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Detection of Haemorrhages in Retinal Images

KEYWORDS: Haemorrhage, Morphological operations, Cellular Neural Network, Thresholding

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ABSTRACT *Now a days in the field of ophthalmology, haemorrhage is the term used more often because of increasing diabetic patients. Its a challenge amidst the ophthalmologist to distinguish the haemorrhage from the blood vessels, this lands in various problems. In the past various techniques were employed for the detection of the haemorrhage but they were not so accurate and often encountered misclassification between haemorrhage and blood vessels. Precise detection and classification of haemorrhage and blood vessel is very important in the diagnosis of many problems. Two algorithms are implemented for the detection of haemorrhages from pathological retinal images. The first algorithm has three main steps namely color image enhancement, image subtraction to extract blood vessels and haemorrhages and use of set of optimally adjusted morphological operators to suppress blood vessels and to highlight only haemorrhages which reduces the misclassification effectively. The second algorithm is based on the concept of Cellular Neural Network which encompasses 2D or 3D arrays of mainly locally connected nonlinear dynamical systems called cells, whose dynamics are functionally determined by a small set of parameters which determine the connection pattern, and are collected into the so-called cloning templates. CNN operates very fast due to its parallel architecture which performs both linear and non-linear image processing tasks, such as filtering, thresholding and various mathematical morphology operations. Here both the algorithms are compared in terms of certain parameters based on specificity, sensitivity to come up with better results.*

1. INTRODUCTION

Retinal haemorrhages are the abnormal bleeding of the blood vessels in the retina, which is the membrane in the back of the eye which is a disorder of the eye in which bleeding occurs into the retina. The retinal haemorrhage is caused by hyper tension, retinal vein occlusion a blockage of a retinal vein, or diabetes mellitus which causes small fragile blood vessels to form, which are easily damaged. Proliferative retinopathy occurs when new blood vessels begin to form in damaged areas of the retina and may lead to spots, floaters or sudden loss of vision. Non proliferative retinopathy occurs when the damaged or leaking blood vessels do not spread.

2. Related Work

The tracking algorithm combined with the neural network [1] is a promising area of investigation to help to correct the misclassification of vessels as pathologies .Here multi –perceptron back propagation technique is successful in segmenting the retinal vasculature in fundus images. The principal component analysis is used to reduce data set before input to neural network. The detection of pathological elements on retinal images are using Cellular Neural Network (CNN) Analog Algorithms [2] consists of large array of processing elements which are identically connected together which operates in fast manner due to the parallel architecture. The brightness of the fundus image was changed by the nonlinear curve with brightness values of the hue saturation value (HSV) space [3]. In order to emphasize brown regions, gamma correction was performed on each red, green, and blue-bit image. Then, this algorithm detects OD, fovea and lesions in the image and determines the type of each lesion based on Morphology [4].

Automatic detection of diabetic retinopathy clinical signs in retinal images would be an important contribution to the diagnosis and screening of the disease[5]. A multilayer perceptron classifier was subsequently used to obtain the final segmentation of red lesions. The algorithm for the detection of Haemorrhages from Diabetic Retinopathy images [6]. These automatically detected haemorrhages are validated by comparing with expert ophthalmologists' hand-drawn ground-truths. The Haemorrhage Assessment System presented is an open access interactive program with graphical user interface [7] allowing the ophthalmically trained user to easily delineate different haemorrhage types, optic disc and fovea. It relies on users to input the haemorrhage borders and thus maintains complete validity for the segments that are being measured.. Image analysis tools can be used for automated detection of these various features and stages of diabetic retinopathy [8] can be referred to the specialist accordingly for intervention. Diabetes mellitus often results in diabetic retinopathy caused by pathological changes of the retinal vessel tree[9].In order to support ophthalmologists in their routine and to enable the quantitative assessment of vascular changes in colour fundus photographs a multi resolution approach was developed which segments the vessel tree efficiently and precisely into digital images of the retina. The multiscale amplitude-modulation-frequency-modulation (AM-FM) methods for discriminating between normal and pathological retinal images are proposed [10]. An automated method to locate the optic nerve in images of the ocular fundus is described. This method uses a novel algorithm we call fuzzy convergence to determine the origination of the blood vessel network [11]. These methods use the convergence of the blood vessel network as the primary feature for detection; in conjunction with the brightness of the nerve as a secondary feature this algorithm identifies the optic nerve as the focal point of the blood vessel network. A method for cup boundary detection from monocular colour fundus image to help quantify cup changes are proposed [12]. The method is based on anatomical evidence such as vessel bends at cup boundary, considered relevant by glaucoma experts. A new method to extract retinal blood vessels from a colour fundus image is described. Digital colour fundus images are contrast enhanced in order to obtain sharp edges [13]. It can be classified as a skeleton based approach working on 3D data sets, and has been designed for a

3. Methods

3.1 Morphological Operations

The proposed method consists of the following steps which are shown in the figure 3.1. Here mathematical morphology constitutes the foundation of morphological image processing which consists of set of operators that transform images according to characterizations such as size, shape, convexity, connectivity and geodesic distance on both continuous and

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discrete spaces.

Contrast stretching and median filtering

In the second step the contrast enhancement is carried out to obtain clear view of blood vessels and pathological or diseased elements called haemorrhages. Normalization is a process that changes the range of pixel intensity values. The purpose of dynamic range expansion in the various applications is usually to bring the image, or other type of signal, into a range that is more familiar or normal to the senses, hence the term normalization. The third step is to obtain the median filtered image .A median filter is more effective than convolution when the goal is to simultaneously reduce the noise and preserve the edges .Median filter of size more than twice as the blood vessel width is used and gray image is subtracted median filtered image .The median filtering is done to reduce the salt and pepper noise found in the image. With this all the structures of retina gets cancelled out except blood vessels and haemorrhages.

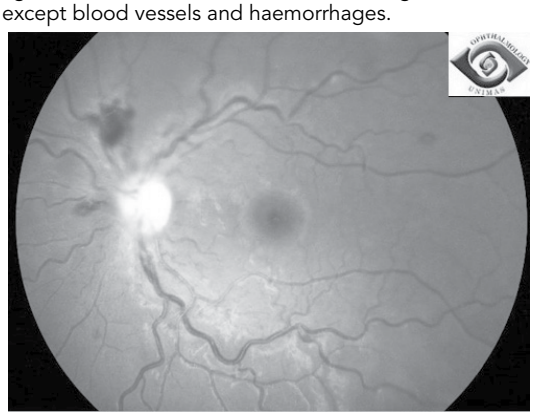
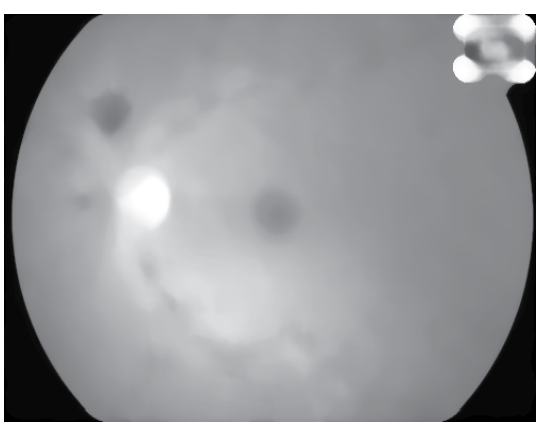
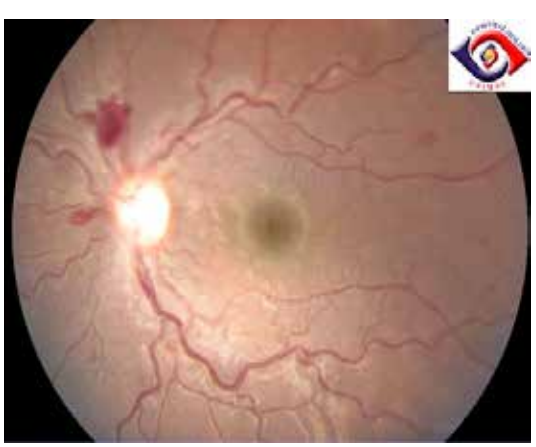


Fig.1 Input Image





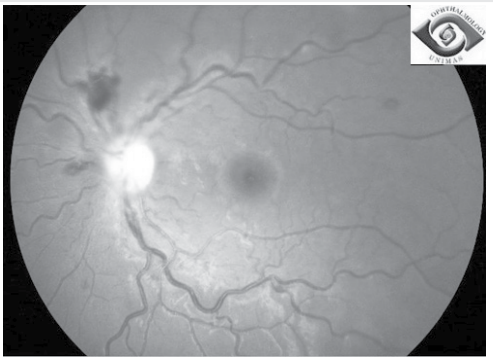
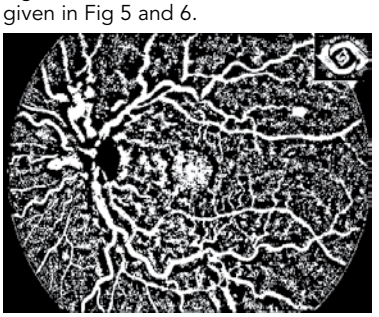


Fig.3Contrast stretching and median filtering

Fourth step is to obtain the subtracted image which includes the subsequent operations shown in Fig 4**.** The gray image is subtracted from median filtered image so that all structures of retina gets cancelled out except blood vessels and haemorrhages. Thresholding is the simplest method of image segmentation. From a grayscale image, thresholding can be used to create binary images. Variants include threshold below, which is opposite of threshold above threshold inside, where a pixel is labeled object if its value is between two thresholds. Object pixel is given a value of "1" while a background pixel is given a value of 0. Image strengthening is done by setting pixel to one if five or more pixel in its 3-by-3 neighborhood are 1's,otherwise set pixel to 0.Image thinning ,erosion and skeletonisation is done with the help of structuring element so that the blood vessels are thinned which are given in Fig 5 and 6.



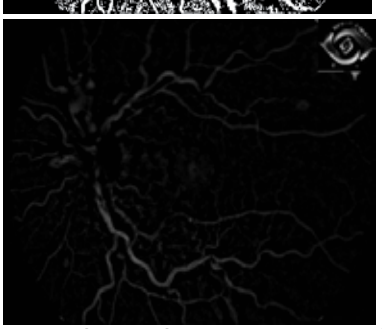


Fig.4 Subtracted image Fig.5 Image Thresholding

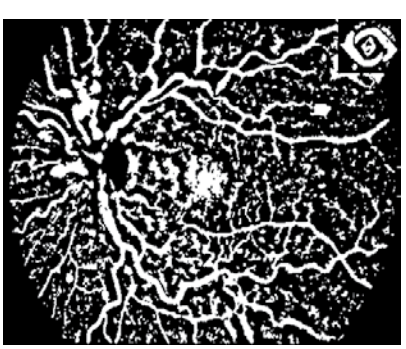


Fig.6 Image strengthening

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Binary Erosion

In binary morphology an image is viewed as a subset of a Euclidean space Rd or the integer grid Zd for some dimension d. The basic idea in binary morphology is to probe an image with a simple, pre-defined shape, drawing conclusions on how this shape fits or misses the shapes in the image. This simple 'probe' is called structuring element, and is called a binary image. Let us consider an image A and structuring element is B its erosion can be obtained from the following equation

$$A \ominus B=\{z \in E|B_{\approx}\subseteq A\} \quad (1)$$

Where B_z is the translation of B by the vector z, i.e.

$$B_{\approx}\{b + z|b \in B\}\forall z \in E \quad (2)$$

When the structuring element B has a center (e.g., a disk or a square), and this center is located on the origin of E, then the erosion of A by B can be understood as the locus of points reached by the center of B when B moves inside A. For example, the erosion of a square of side 10, centered at the origin, by a disc of radius 2, also centered at the origin, is a square of side 6 centered at the origin.

The erosion of A by B is also given by the expression:

$$A \ominus B = \cap_{b\in B} A_{-b} \quad (3)$$

Dilation

Dilation is one of the basic operations in mathematical morphology. Originally developed for binary images, it has been expanded first to grayscale images, and then to complete lattices. The dilation operation usually uses a structuring element for probing and expanding the shapes contained in the input image.

In binary morphology, dilation is a shift-invariant (translation invariant) operator, strongly related to the Minkowski addition. A binary image is viewed in mathematical morphology as a subset of an Euclidean space R^d or the integer grid Z^d, for some dimension. Let E be a Euclidean space or an integer grid, A a binary image in E, and B a structuring element. The dilation of A by B is defined by:

$$A \oplus B = \bigcup_{b\in B} A_b \quad (4)$$

The dilation is commutative, also given by:

$$A \oplus B = B \oplus A = \bigcup_{a\in A} B_a \quad (5)$$

If B has a center on the origin, then the dilation of A by B can be understood as the locus of the points covered by B when the center of B moves inside A. The dilation of a square of side 10, centered at the origin, by a disk of radius 2, also centered at the origin, is a square of side 12, with rounded corners, centered at the origin. The radius of the rounded corners is 2.

The dilation can also be obtained by:

$$A \oplus B = \{z \in E|(B^s{}_{\approx} \cap A \neq \phi\} \quad (6)$$

where B^s denotes the symmetric of B, that is,

$$B^s = \{x \in E| - x \in B\}. \quad (7)$$

Fig.7 image after dilation Fig.8 Image after

Closing Operation

Fig.9 Complemented image

Image Complement

The image complement block computes the complement of a binary, intensity or RGB images. For binary images, the block replaces pixel values equal to 0 with 1 and pixel values equal to 1 with 0. For an intensity or RGB image, the block subtracts each pixel value from the maximum value that can be represented by the input data type and outputs the difference.The final step is to label the pathological elements called haemorrhages .The haemorrhages are labelled one by one and the total count of haemorrhages and the area occupied by the haemorrhages were found.

3. 2 Analog Algorithms

Cellular Neural Network

CNNs can be defined as 2D or 3D arrays of mainly locally connected nonlinear dynamical systems called cells, whose dynamics are functionally determined by a small set of parameters which control the cell interconnection strength. These parameters determine the connection pattern, and are collected into the so-called cloning templates, which, once determined, define the processing of the whole structure

Basic Characteristics of CNN

The CNN can be defined as an M x N type array of identical cells arranged in a rectangular grid. Each cell is locally connected to its 8 nearest surrounding neighbors. Each cell is characterized by u_{ij}, y_{ij} and x_{ij} being the input, the output and the state variable of the cell respectively. The output is related to the state by the nonlinear equation:

$$y_{ij}(t)= f(x_{ij})= 0.5 (|x_{ij}(t)+ 1|- |x_{ij}(t)- 1|) \quad [8]$$

The state transition of neuron (i, j) is governed by the following differential equation:

$$C\left(\frac{dx_{ij}(t)}{dt}\right)=-\frac{1}{R_x}x_{ij}(t)+\sum A_{ijkl}Y_{kl}(t)+\sum B_{ijkl}U_{kl}(t)+I \quad [9]$$

Where C(i,j) represents the neuron at column i, row j. The coefficients A (i, j, k, l) and B (i, j, k, l) are known as the cloning templates. In general, they are nonlinear, time- and space variant operators.

Detection of Blood Vessels And Haemorrhages Using Thresholding And Morphological Operations

Morphological operations can be performed on binary im-

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ages using CNN operators .Thus the preliminary step is to obtain a convenient binary image from the original retinal image through a thresholding task using a properly chosen threshold value.First an erosion operation is performed with an usually circular structural element .In a given number of successive steps ,all of the image details are removed through erosion while the largest elements like the compact spots representing haemorrhages are eroded but they still remain on binary images. The erosion operation may continue until most of smaller objects decrease to few pixels which are removed using morphological operation called small object killing.

Fig 10 The GUI Document without input image

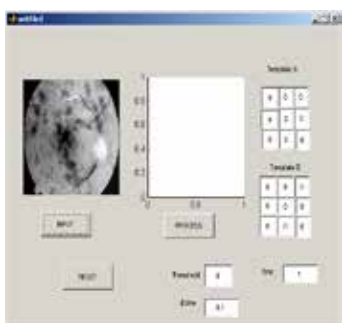

Fig 11 pathological input image

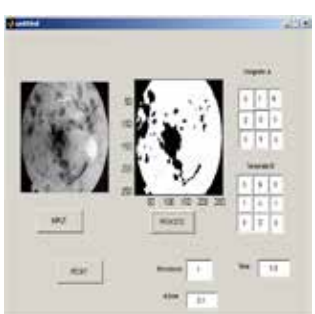

Fig 12 The detected haemorrhages

4. Results and Discussions

The haemorrhages were detected using two methods a) Morphological Methods b) Analog Algorithms. The Morphological methods includes the following steps such as color to gray scale conversion, contrast enhancement, median filtering ,image subtraction, image thresholding, image strengthening, image thinning, erosion and skeletonisation ,Morphological closing and component labelling. The second method is based on analog algorithms where the Graphical User Interface is used .The retinal image is given as input to GUI blank document and with consecutive steps in terms of differential time and change in threshold values, the erosion operation occurs which erases all the image details including blood vessels while the largest pathological elements such as haemorrhages remains consistent. The results of morphological methods are given from fig.1 to 9 and the results of analog algorithms are given below from fig.10 to 12.The following is the table which encompasses the true positive ,false positive,true negative,false negative ,sensitivity ,specificity, probability values and area for the five retinal images.

Table 1: Performance Metrics

Image	TP	FP	TN	FN	Sensitivity	Specificity	PV
Image1	586	50.9	535398	271	68.3	99.9	92.0
Image2	755	65.6	536877	272	73.5	99.9	92.0
Image3	2967	258	538356	273	91.5	99.9	92.0
Image4	3044	264	542793	275	91.7	99.9	92.0
Image5	1490	129	535398	271	84.5	99.9	92.0

Table 2: Haemorrhage Area

Image	Number of labels	Area occupied by haemorrhages
Image1	4	637 pixels
Image2	25	3309 pixels
Image 3	20	3226 pixels
Image 4	4	821 pixels
Image 5	7	1620 pixels

5. CONCLUSION

This paper presents a fast and reliable approach for detecting haemorrhages .This method is developed to detect haemorrhages from diabetic retinopathy images.The haemorhages were detected using morphological operators such as dilation ,erosion ,image opening and closing operations .These subsequent operations help in detection of haemorrhages to facilitate opthamologists decision on severity of disease . Here the haemorrhage detection using morphological operators are analyzed, The input retinal image is converted into gray scale image .The gray scale image is enhanced using contrast enhancement. The median filtering is applied to enhanced image to reduce 'salt and pepper noise'. The median filter of size more than twice the blood vessel width is used and gray image is subtracted from the median filtered image. Blood vessels are clearly visible by means of image subtraction. Here the threshold value is chosen as three so that the blood vessels and haemorrhages are clearly seen. Image strengthening is done by setting pixel to one if five or more pixel in its 3-by-3 neighborhood are 1's,otherwise set pixel to 0.Image thinning ,erosion and skeletonisation is done with the help of structuring element so that the blood vessels are thinned. Then morphological closing which encompasses dilation followed by erosion is done to suppress blood vessels completely and to get actual size of haemorhage so the complemented image is obtained and the component labelling is done to obtain the total count of haemorrhages and the area occupied by the haemorrhages.

The second method is based on analog algorithms where the Graphical User Interface (GUI) is used .The retinal image is given as input to GUI blank document and with consecutive steps in terms of differential time and the change in template parameters and threshold values ,the erosion operation occurs which erases all the image details including blood vessels while the largest elements remains consistent compared to rest of image details .Fewer erosion steps continue until most of smaller objects decrease to fewer pixels where they can be removed using morphological operation called small object killing. The future work may address an issue of improving the results of other tasks such as detection of faint and small haemorhages.

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