RETINAL MICROANEURYSM DETECTION ON OPTIC DISC THROUGH CROSS-SECTION PROFILE ANALYSIS

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Abstract

Diabetic Retinopathy (DR) is a most popular diabetic eye disease that develops in most of the patients caused by changes in retina with long-standing illness. Diagnosis of DR is performed by the evaluation of retinal images. The presence of microaneurysms (MAs) on the retina is the primary factor and main characteristic symptom of this disease. MA-like structures do appear on the optic disc. Optic disc (OD) detection is an important step while developing automated screening systems for Diabetic Retinopathy.A method to automatically detect the position of the OD in digital retinal fundus images starts by normalizing luminosity and contrast throughout the image using illumination equalization and adaptive histogram equalization methods respectively. The MA detection is applied through the finding of directional cross-section samples and peak detection is applied on each sample and a set of attributes regarding the size, height and shape of the peak are calculated consequently. The naïve Bayes (NB) classification is used in the feature set to exclude the spurious candidates. Finally, the MA score is calculated for the remaining candidates and the points with non-maximal score in a candidate region are not considered.

Keywords*: Image Processing, Diabetic Retinopathy, microaneurysms, Bio- Imaging, naïve Bayes Classification.*

Introduction

Image processing is a technique to develop raw images received from capturing devices camera/sensor placed on satellites, space probes and aircrafts or pictures taken in normal day-today life for various applications. various techniques and tools have been developed in image processing during the last four to five decades. most of the techniques are developed for improving clarity of images obtained from unmanned spacecrafts, space probes and military reconnaissance flights. Image processing systems are becoming popular due to easy availability of powerful personnel computers, large size memory devices, graphics software's etc.

Methods of Image Processing

There are two methods available in image processing

a) Analog Image Processing

Analog Image Processing system refers to the alteration of image through electrical means. The most common example is the TV image. The television signal is a different voltage level which varies in amplitude to represent brightness through the image. Electrical signal varies, the displayed image appearance is altered. The brightness and contrast controls on a TV set serve to adjust the amplitude and reference of the video signal, resulting in the brightening, darkening and alteration of the brightness range of the displayed image.

b) Digital Image Processing

In digital image processing system, digital computers are used to process the image. The image will be converted to digital form using output devices scanner – digitizer and then processing is done. It is defined as the subjecting numerical representations of objects to a series of operations in order to obtain a desired result. It starts with one image and produces a modified version of the same. It is therefore a process that takes an image into another. The term digital image processing generally refers to processing of a two-dimensional picture by a digital computer. In a broader perspective, it implies digital processing of any two-dimensional data. A digital image is an array of real numbers represented by a finite number of bits. The principle advantages of digital image processing methods are its versatility, repeatability and the preservation of original data precision.

Image Pre-Processing Techniques

- Image representation
- Image pre-processing
- Image enhancement
- Image restoration
- Image data compression

Applications of Image Processing

Image processing is used in various applications such as:

- In medical, image processing is used to develop a system capable of determining human blood types for emergency situations and so with fast response
- In forensic studies, image processing can be a useful tool in the forensic examination and extraction of information from contested figures and images
- In textile industry, image processing is used to determine yarn mass parameters as well as yarn production characteristics
- In military, the main objective of the work is to achieve the automatic evaluation of surveillance pictures
- In radiology, doctors use the equipment built with image processing technology for the detection of health problems such as cancerous tumors and blockages in blood vessels
- Police detectives use digital photo processing technology that is designed to detect specific faces, which helps them in apprehending criminals.
- Graphic designers and animation artists use image processing to create illustrations and computer game characters
- Angiography is a specific application of image signal processing that renders highly contrasted images of a patient's blood vessels and any potentially dangerous clots or plaques within them
- Image processing applications can also be found in computerized axial tomography (CAT) scans, which have improved the rates of early cancer detection and have thus increased patients' chances of recovery

Bio-Medical Engineering

Bio- Medical Engineering is the broad area of engineering principles and design concepts to medicine and biology. This field seeks to close the gap between engineering and medicine: It combines the design and problem solving skills of engineering with medical and biological sciences to advance healthcare treatment, including diagnosis, monitoring, treatment and therapy. Biomedical engineering is one of the recently emerged as its own discipline, compared to many other engineering fields. Such an evolution is common as a new field transitions from being an interdisciplinary specialization among already-established fields, to being considered a field in itself. Most of the work in biomedical engineering consists of research and development, spanning a broad array of subfields (see below). Prominent biomedical engineering applications include the development of biocompatible prostheses, various diagnostic and therapeutic medical devices ranging from clinical equipment to micro-implants, common imaging equipment such as MRIs and EEGs, regenerative tissue growth, pharmaceutical drugs and therapeutic biological. In biomedical processing system medical Imaging relates knowledge of a unique physical phenomenon (radiation, sound, magnetism etc.) with high-speed electronic data processing, examine and display to generate an image. Often, these images can be obtained with minimal or completely non invasive procedures, making them less painful and more readily repeatable than invasive techniques. Examples include Magnetic Resonance Imaging (MRI), ultrasound and computed tomography (CT). Medical imaging is the technique and process used to create images of the human body (or parts and function thereof) for clinical purposes (medical procedures seeking to reveal, diagnose, or examine disease) or medical science (including the study of normal anatomy and physiology). Removal of organs and tissues can be performed for medical reasons, such procedures are not usually referred to as medical imaging, but rather are a part of pathology. Measurement and recording techniques which are not primarily designed to produce images, such as electroencephalography (EEG), magneto encephalography (MEG), electrocardiography (EKG), and others, but which produce data susceptible to be represented as maps (i.e., containing positional information), can be seen as forms of medical imaging. In the clinical context, "invisible light" medical imaging is generally equated to radiology or "clinical imaging" and the medical practitioner responsible for interpreting (and sometimes acquiring) the images are a radiologist. "Visible light" medical imaging involves digital video or still pictures that can be seen without special equipment. Dermatology and wound care are two visual representations that utilize visible light imagery. Diagnostic radiography designates the technical aspects of medical imaging and in particular the acquisition of medical images. The radiographer or radiologic technologist is usually responsible for obtaining medical images of diagnostic quality, although some radiological interventions are performed by radiologists. While radiology is an evaluation of anatomy, nuclear medicine provides functional assessment.

As a field of scientific research, medical image processing system is a part of a sub-discipline of biomedical engineering, medical physics or medicine depending on the context: Research and development in the area of instrumentation, image acquisition (e.g. radiography), modeling and quantification are usually the preserve of biomedical engineering, medical physics, and computer science; Research into the application and interpretation of medical images is usually the preservation of radiology and the medical sub-discipline relevant to medical condition or area of medical science (neuroscience, cardiology, psychiatry, psychology, etc.) under investigation. Most of the techniques developed for medical imaging also have scientific and industrial applications.

Medical imaging is often perceived to designate the set of techniques that noninvasively produce images of the internal aspect of the body. In this restricted sense, medical imaging can be seen as the solution of mathematical inverse problems. This means that cause (the properties of living tissue) is inferred from effect (the observed signal). In the case of ultrasonography the probe consists of ultrasonic pressure waves and echoes inside the tissue show the internal structure. In the case of projection radiography, the probe is X-ray radiation which is absorbed at different rates in different tissue types such as bone, muscle and fat. Medical imaging has revolutionized the medicine by providing cost-efficient healthcare and effective diagnosis in all major disease areas. Medical imaging allows scientists and physicians to understand potential life-saving information using less invasive techniques. In medical imaging the quality of the image acquisition and the image interpretation determines the accuracy of diagnosis. Computers have a huge impact on the acquisition of medical images. They perform multi-pronged functions like controlling imaging hardware performing reconstruction, post-processing of the image data and storing the scans. In contrast, the role of computers in the interpretation of medical images has so far been limited. Interpretation remains an almost exclusively human domain.

Structure of the Eye

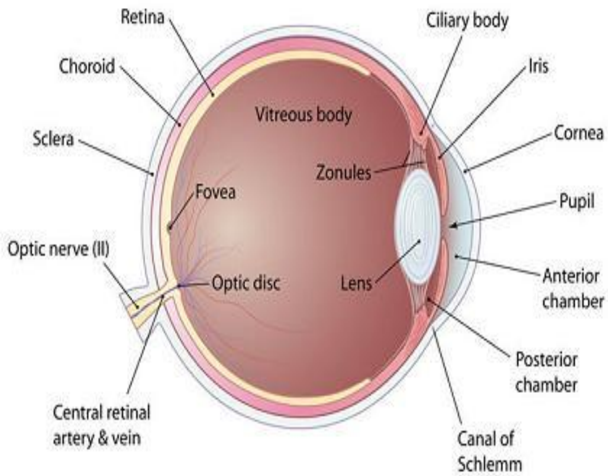

Fig: 1 – Structure of the eye

- Optic disc – It is the place where blood vessels converge
- Fovea – It is the part of the eye, located in the center of the macula region of the retina
- Retina – It is the light – sensitive layer which lines the inner surface of the eye
- Sclera – It is the white part of the eye
- Pupil – It is the black part of the eye

Related Work

Diabetic Retinopathy (DR) is one of the complications of diabetes that develops in most of the patients with long- standing illness, and the leading cause of blindness in the developed countries. Effective treatments for DR are available, though it requires early diagnosis and the continuous monitoring of diabetic patients. Diagnosis of DR is performed by the evaluation of retinal images. Some of the papers related to the project are below;

1. This paper presents the mathematical morphology method to detect and eliminate the optic disc (OD) and the blood vessels. Detection of optic disc and the blood vessels are the necessary steps in the detection of diabetic retinopathy because the blood vessels and the optic disc are the normal features of the retinal image. And also, the optic disc and the exudates are the brightest portion of the image. Detection of optic disc and the blood vessels can help the ophthalmologists to detect the diseases earlier and faster. Optic disc and the blood vessels are detected and eliminated by using mathematical morphology methods such as closing, filling, morphological reconstruction and Otsu algorithm. The objective of this paper is to detect the normal features of the image. By using the result, the ophthalmologists can detect the diseases easily.
2. In this paper, the detection of microaneurysms is a key element as a new microaneurysms segmentation technique has been proposed based on a novel application of the radon transform, which is able to identify these lesions without any previous knowledge of the retina morphological features and with minimal image preprocessing. The algorithm has been evaluated on the Retinopathy Online Challenge public dataset, and its performance compares with the best current techniques. The performance is particularly good at low false positive ratios, which makes it an ideal candidate for diabetic retinopathy screening systems.
3. A method for the automatic detection of microaneurysms (MAs) in color retinal images is proposed in this paper. The recognition of MAs is an essential step in the diagnosis and grading of diabetic retinopathy. The proposed method realizes MA detection through the analysis of directional cross-section profiles centered on the local maximum pixels of the preprocessed image. Peak detection is applied on each profile, and a set of attributes regarding the size, height, and shape of the peak are calculated subsequently. The statistical measures of these attribute values as the orientation of the cross-section changes constitute the feature set that is used in a naïve Bayes classification to exclude spurious candidates. We give a formula for the final score of the remaining candidates, which can be thresholded further for a binary output. The proposed method has been tested in the Retinopathy Online Challenge, where it proved to be competitive with the state-of-the-art approaches. We also present the experimental results for a private image set using the same classifier setup.
4. In this research paper, the authors proposed a MA detector that provides remarkable results from two aspects. One way is to ensure high reliability and raise accuracy to consider ensemble-based systems. In MA detection, detectors provide spatial coordinates as centers of potential MA candidates. The use of well-known ensemble techniques would require a classification of each pixel, which can be misleading in our context, since different algorithms extract MAs with different approaches and the MA centers may not coincide exactly. To overcome this difficulty, close MA candidates of the individual detectors are gathered and applied a voting scheme on them. In this research, a framework to build MA

detector ensembles is proposed based on the combination of the internal components of the detectors not only on their output as. To increase the accuracy of such ensembles, identification of the weak points of MA detection is a must. Most MA detectors tackle this problem in the following way: first, the green channel of the fundus image is extracted and preprocessed to enhance MA like characteristics. Then, in a coarse level step (which will be referred as candidate extraction in the rest of this research), all MA-like objects are detected in the image. Finally, a fine level algorithm (usually a supervised classifier) removes the potentially false detections based on some assumptions about MAs. The former investigations showed that the low sensitivity of MA detectors originates from the candidate extractor part. However, the sensitivity could be increased by applying proper preprocessing methods before candidate extraction. This technique causes a slight increment in the number of false positives, but it can be decreased by classification or voting. In this research, an effective MA detector based on the combination of preprocessing methods and candidate extractors has been proposed .An ensemble creation framework to select the best combination has been provided . An exhaustive quantitative analysis is also given to prove the superiority of our approach over individual algorithms. The grading performance of our method, which is proven to be competitive with other screening systems, has been investigated.

5. The disease diabetes has been thriving on the developing countries with a very fast rate. Prolonged Diabetes serves as the root of many comorbidities such as hypertension, cardiovascular diseases, kidney disorders etc. One of the comorbid condition includes retinal disorder which is commonly known as `Diabetic Retinopathy'(DR). In Diabetic retinopathy, retinal vessels are damaged due to high sugar level in the blood. Diabetic Retinopathy may cause irreversible blindness to the person. The visual impairment can be prevented if the condition is diagnosed early and by regularly consulting an expert ophthalmologist. But the number of patients to be checked for the disease is more as compared to the number of experts available in the field. Therefore we need a computerized screening system that will distinguish between a healthy or DR affected person. Thus the primary screening is done by the computerized scheme so that the workload of ophthalmologists can be reduced. According to the ophthalmologists, the earliest evidence for DR presence is Microaneurysm (MA). Thus accurate detection of these lesions leads to the early detection of disease. Computerized diagnosis insures reliable and accurate detection of MAs. The paper describes a computerized method for detection of MAs.
6. The automation of screening of diabetic retinal fundus images is widely studied. It is essential for early detection of diabetic retinopathy. The automated systems involve accurate detection of lesions like microaneurysms as they play vital role in the grading of diabetes. This paper proposes microaneurysms detection in three simple steps. The coarse segmentation using Canny's edge gradient,the feature extraction using Differential Morphological Profiles and classification of regions. The Differential Morphological Profiles are used to provide local features like size, shape and intensity of the objects. The use of local information limits the need of high dimensional classification. The work also shows

that the combination of differential morphological profile with statistical features increase classification accuracy.

Proposed Work

Optic disc (OD) detection is a main step while developing automated screening systems for Diabetic Retinopathy. A method to automatically detect the position of the OD in digital retinal fundus images starts by normalizing luminosity and contrast throughout the image using illumination equalization and adaptive histogram equalization methods respectively. The advantages of implemented system are; It achieves better result compared with the existing system, the performance has been increased and the MA has been detected accurately in the area of optic disc.

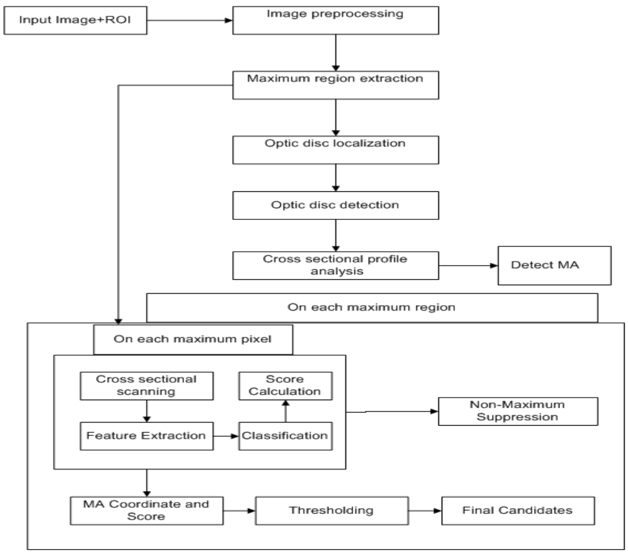

Fig: 2 - Dataflow Diagram

i. Modules

a) Image pre processing

Preprocessing is beneficial to consider a certain amount of image smoothing before the actual step of detection. This is partially due to the fact that many images are available in the lossy compressed format resulting in the distortion of small structures such as MAs. The proposed method particularly relies on the local intensity distribution of MAs, it is important to reduce the effect of noise. In this, convolution with a Gaussian mask with a variance of 1.0. This amount of smoothing suppressed noise sufficiently while preserving true MAs.

b) Local Maximum Region Extraction

A simple breadth-first search algorithm is applied for the calculation of grayscale morphological reconstruction. Pixels of the image are processed sequentially, and compared to their 8-neighbors. If all neighbors have a lower intensity, then the pixel itself is a LMR. If there is a neighboring pixel with higher intensity, then the current pixel may not be a maximum.

c) Cross-Sectional Scanning

To examine the surrounding of a single maximum pixel in a MA candidate region, the intensity values along discrete line segments of different orientations, whose central pixel is the candidate pixel, are recorded. In this way, a set of cross-sectional intensity profiles is obtained.

d) Peak Detection and Property Measurement on the Cross-Section Profiles

On the obtained cross-section profiles a peak detection step is performed. Our aim is to decide whether a peak is present at the centre of the profile, i.e., at the location of the candidate point for a specific direction. We calculate several properties of the peak, and the final feature set consists of a set of statistical measures that show how these values vary as the orientation of the cross-section is changing. This way, the variation of important characteristics, such as symmetry and shape of the structure, and its difference from the background may be numerically expressed.

e) Optic disc localization

Localization of the optic disc is the first step in the technique. The purpose of localization is to have low processing rate and less computational cost in further steps. Steps for OD detection are as follows:

- Image is pre-processed by averaging mask of size 31x31, in order to remove the background artifacts which can cause false localization.
  where, Z's are values of image gray levels and R is the smoothed image
- Detect maximum gray values in an image histogram because the gray values of optic disc are brighter than the background value

f) Optic Disc Detection

After localizing the optic disc we have to define the region of interest (ROI) for increasing the performance of optic disc detection. After smoothing the size of ROI was set to 130 x 130. After extraction of ROI, we have to detect the optic disc boundary using Hough Transform. The Hough Transform is used to identify the locations and orientations of retinal image features. This transform consists of parameterized description of a feature at any given location in the original image space

[11]. It can be used for representing objects that can be parameterized mathematically as in our case, a circle, can be parameterized by following equation.

$$(x-a)^2 + (y-b)^2 = r^2$$

where (a, b) is the coordinate of centre of the circle that passes through (x, y) and r is its radius.

g) Feature Set and Classification

After the cross-sectional scanning and peak detection steps are performed for every scan direction on a given candidate, we calculate several statistical measures of the resulting directional peak properties. The increasing-and decreasing ramp height values are stored in the RHEIGHTS set, likewise, the ramp slope values are stored in RSLOPES. The TWIDTHS, PWIDTHS, and PHEIGHTS sets contain the top width, peak width, and peak height values, respectively. Let μt, σt and CVt denote the respective mean, standard deviation and coefficient of variation of the values in set T, where the coefficient of variation is the ratio of the standard deviation and the mean, i.e., $CV = \sigma/\mu$. We consider the following feature set for classification:

F={μ PWIDTHS,σPWIDTHS,μTWIDTHS,σTWIDTHS,σRSLOPES,CVRHEIGHTS,CVPHEIGHTS}

For classification, a naïve Bayes (NB) classifier, a simple and robust probabilistic algorithm that assumes the individual features to be independent is used. The training set consists of both positive and negative MA examples.

h) MA Score Calculation and Non-maximum Suppression

To meet the requirements of a real-life DR screening system, score values are assigned to the MA candidates that were classified as true MAs, which score considers the shape, symmetry, sharpness and contrast of the candidate. The score is constructed in such a way that stronger, more visible MAs achieve higher score than faint ones. The MA score is calculated using the formula

$$score = \frac{min_{PHEIGHTS} \cdot \mu_{RSLOPES}}{1 + \sigma_{PWIDTHS} + \sigma_{TWIDTHS} + \sigma_{RSLOPES} + \sigma_{RHEIGHTS} + \sigma_{PHEIGHTS}}$$

Conclusion and Future Work

Conclusion

The detection of MAs on the optic disc is based on the principle of analyzing directional cross-section profiles centered on the candidate pixels of the preprocessed image. The number of pixels to be processed is significantly reduced by only considering the local maxima of the preprocessed image. We apply peak detection on each profile, and calculate a set of values that describe the size, height, and shape of the central peak. The statistical measures of these values as the orientation of the cross-section changes constitute the feature set used in a classification step to eliminate false candidates. A formula to calculate the final score of the remaining candidates based on the obtained feature values is proposed. Experimental result provides better result when compare with the existing one.

Future work

Future work includes automatic fovea detection as an extension of the present work. Fovea is the most important part of the eye for human vision, located in the center of the macula region of the retina. The fovea is responsible for sharp central vision which is necessary in humans for activities where visual detail is of primary importance, such as reading and driving**.** The size of fovea zone in retinal eye images has a relation with various diseases and when the delicate cones of the fovea are destroyed, it may lead to blindness.

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