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Glaucoma Detection in Ultrasound Biomicroscopy Images by Parametric Analysis

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ABSTRACT

Biomedical image processing has experienced a dramatic expansion in research field. The processing and classification of medical images has gradually improved the resolution leading to detailed gray scale images. Along with the development of new technologies and usage of various imaging modalities the number of challenges has also increased. The present proposal proposes a novel method for detection of abnormalities in the anterior chamber of eye during the early stages of glaucoma. The increased pressure in the intraocular region can damage the optic nerve leading to a defect called glaucoma. One of the major complication related to glaucoma is, if glaucoma is not treated on time it can cause total permanent blindness within a few years. Ultrasound Biomicroscopy is a technique that works on the principle of ultrasonography to detect the abnormalities present in deep inner layers of the cornea. The principal objective of this project is to reduce speckle noise and categorize the statistical and morphological features. Several noise reduction filters are used for the pre-processed of UBM images. The proposed proposal aims to provide cross sectional images of anterior chamber of the eye with high resolution. The linear SVM filter being the most effective one is used to differentiate and classify the normal and glaucomatous image.

Keywords: *Ultrasound Bio-Microscopy, Glaucoma, Linear SVM*

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Introduction

The use of computers in facilitating the processing and analysis of medical images has become necessary due to the increase in number of diseases. Glaucoma is one such chronic eye disorder that damages the optic nerve and gradually leads to permanent blindness. It is termed as silent thief of eye as its symptoms occur only when it is quite advanced and hence it is critical to detect it on-time. The aqueous fluid continuously produced by the eye must be drained to maintain normal pressure in the eye. When the aqueous fluid's drainage path gets blocked due to trauma or infections, the fluid gets accumulated that leads to increase in pressure. This process results in damage of optic nerve which gradually causes glaucoma. Ultrasound Biomicroscopy is a technique that uses high frequency ultrasound to produce high resolution detailed gray scale images. It was developed in late 1980s by Pavlin, Sherar, Foster in Toronto.UBM allows to acquire in vivo images of the deep ocular segments in a non- invasive way. The structural details can be captured at near microscopic resolution and it can be evaluated both qualitatively and quantitatively. Any deformity in the anterior chamber can be identified by analyzing the UBM image.

Literature Survey

A novel method has been proposed for standardized imaging and measurement of anterior segment of eye. The reliability analysis is done using UBM and ImageJ software where 45 structural parameters were measured in UBM images of patients with cataract, glaucoma and dysgenesis and a good IOR and IOA were yielded, based on preplaced landmarks, in the quantitative assessment of anterior segment structures[1]. Several algorithms have also been proposed to detect glaucoma in retinal fundus image and classification has been done based on the severity of certain methods such as green channel extraction, filtering etc. The features were extracted and were classified using ANFIS and SVM. Certain parameters such as specificity, accuracy and sensitivity were evaluated and compared to diagnose the glaucoma disorder [2]. Several researchers have made a prospective observational study on the features of upper eyelid in healthy and different types of congenital ptosis cases using 50MHz probe. Lid-thickness, tarsal-thickness, orbicularis oculi and Levator-Muller-orbital Septum-conjunctival Complex (LMSC) were measured in primary gaze, compared between four groups and the results were analyzed statistically using ANOVA test. This study showed that various eyelid structures can be identified with good anatomical correspondence and structural alterations of eyelids can be studied in normal and different types of congenital ptosis conditions respectively with the help of UBM [3]. It is also studied that ultrasound pachymetry (UP) and ultrasound bio-microscopy (UBM) produce similar central corneal thickness (CCT) measurements in human patients [4]. An algorithm was designed for premature detection of primary open angle glaucoma in retinal fundus images where preprocessing methods such as histogram equalization and 2-D median filter enhanced the image quality and removed the noise from the images [5]. The preprocessing techniques such as illumination correction, segmentation of blood vessel and inpainting were applied to the images and features were extracted from the optic disc and optic cup. Later depending upon the technique various classifiers such as SVM, back propagation neural network, and ANFIS, were used to differentiate between normal and abnormal cases of glaucoma[6]. UBM and AS-OCT both technologies were able to produce real time high resolution cross-sectional images upon which biometric descriptors can be used for quantitative characterization, diagnosis, as well as surgical management of glaucoma [7].The parameters such as anterior chamber depth (ACD), lenticular thickness (LT), angle opening distance (AOD), iris–lens contact distance(ILCD), and trabecular-ciliary process distance(TCPD),, Absolute lenticular position (ALP), Axial length (AL), and relative lenticular position (RLP) were measured and concluded that phacomorphic glaucoma(PG) eyes have an anatomical predisposition to develop primary narrow angle glaucoma[8]. A semi-automated algorithm was proposed for the screening of glaucoma by measuring spatial parameters such as Anterior Chamber Area (ACA), Trabecular Iris Space Area (TISA), Angle of Departure (AOD) etc which lead to the conclusion that these parameters provided a reasonable range limit for diagnosing closed angle glaucoma [9]. Several research works were also carried out depending on the simulation results obtained from an eye segmentation process [10].

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Methodology

The initial step involved the collection of UBM images. The input UBM image is enhanced by reducing speckle noise using despeckling filters such as Linear filter, Median filter, Anisotropic diffusion filter, Speckle anisotropic diffusion filter(srad). It was found that linear filter efficiently reduces speckle noise in UBM images compared to other despeckling filters by measuring their efficiency through statistical and image quality metrics analysis. The images had to be pre processed to select an appropriate region of interest. In glaucoma, as the fluid gets accumulated on the outer edge of the iris, the structure of the iris gradually changes. Thus the iris region is taken as the region of interest. Statistical parameters such as Mean, Median, S.D., Skewness, Kurtosis and Morphological parameters such as Iris Area, Iris Perimeter, Angle, Angle of Departure(AOD),Angle recess area(ARA) were computed. The statistical analysis and some of the morphological analysis namely iris area, iris perimeter and angle were performed using ImageJ software whereas the angle morphological parameters namely AOD and ARA were evaluated using MATLAB.

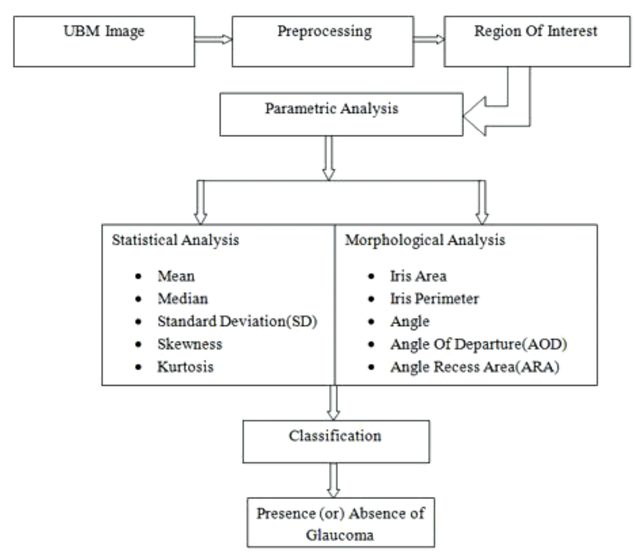

Fig. 1: Flow Diagram for Detection & Classification of Glaucoma

The morphological analysis included quantitative parameters such as Iris Area, Iris Lens Contact Distance (ILCD), Iris Lens Angle (ILA), Iris Volume, Iris concavity/convexity and Chamber Volume.

Iris Area: The Iris area was calculated by marking the iris region manually through freehand sketching using ImageJ software. The total area of the Iris was calculated and the histogram was also analyzed [11]

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Iris Perimeter: In ImageJ software, through freehand sketching, the iris region is marked manually and the boundary of the iris is evaluated for which the histogram is also analyzed.

Angle: The human eye continuously produces a fluid called aqueous humor. The drainage of this fluid is important as the accumulation may lead to glaucoma or blindness. So the Angle refers to the drainage angle inside the eye that controls the outflow of the aqueous humor. It is the intersection point of cornea and iris where the blockage occurs [12] It is measured by marking it manually from the apex point to the cornea and iris.

Angle of Departure (AOD): The perpendicular distance between the iris and the perpendicular distance between the trebecular meshwork is referred to as angle of departure. This point lies 0.5mm (500µm) anterior to the scleral spur. The only anatomical landmark which is used as a reference point to measure AOD is the scleral spur [13]. Thus the input parameters considered for measuring AOD are Scleral Spur and apex point.

Trabecular Iris Space Area (TISA): The area between the Angle opening distance 0.5mm and the perpendicular line drawn from scleral spur till it reaches iris (at 0.5mm) is known as the Trabecular Iris Space Area [14]. It is calculated using the area of trapezium formula as given below in equation (1).

$$\text{Area of Trapezium} = h(a+b)/2 \qquad \ldots(1)$$

Where, a – length of one parallel slide;

b – length of the other parallel slide;

h – height of the trapezium

Angle Recess Area (ARA): Angle Recess Area refers to the total area lying in between the AOD 500µm and the apex point. Mathematically it is calculated as the summation of TISA and the triangular area between the apex point and the perpendicular line from scleral spur[15]. So, to get ARA, first TISA is calculated using the trapezium formula as discussed above and then the triangular area in the apex region is computed using the area of triangle formula as given below in equation (2).

$$\text{Area of Triangle} = \sqrt{s(s-a)(s-b)(s-c)} \qquad \ldots(2)$$

Where, a,b,c are length of sides of triangle;

s = (a+b+c)/2

Thus, the statistical and morphological parameters analyzed for the UBM images are then subjected to classification for classifying the normal and abnormal images using Linear SVM (Support Vector Machine) classifier. Then the actual and predicted values of classification are obtained for analysing the performance of the classifier.

Result and Discussion

The UBM images of the eye are generally grayscale images. In the proposed work 10 normal and 10 abnormal images were taken. These images were despeckled using Linear filter, Median filter, Anisotropic diffusion filter, Speckle anisotropic diffusion filter(srad) and it was concluded that linear filter works efficiently on UBM images. The efficiency of these filters were measured through the analysis and comparison of certain filters and image quality parameters. The iris region was selected as the region of interest and then the statistical parameters such as Mean, Median, S.D., Skewness, Kurtosis and Morphological parameters such as Iris Area, Iris Perimeter, Angle, Angle of Departure(AOD), Angle recess area(ARA) were computed for both normal and abnormal UBM images and tabulated as shown below in table 1&2 respectively.

Table 1: Statistical and Morphological Parameters of Normal UBM Images

Images	Mean	Median	S.D.	Skewness	Kurtosis	Iris Area (in mm²)	Iris Perimeter (in mm)	Angle (in deg)	AOD _500 (mm)	ARA _500 (mm²)
Image1	117.9	117	62.27	0.246	-0.42	5.55	418.46	30.49	0.874	0.211
Image2	133.7	181	58.92	-0.795	0.727	6.89	422.92	39.48	0.723	0.142
Image3	87.33	86	25.59	0.31	0.346	5.19	434.51	25.99	0.253	0.064
Image4	77.46	75	29.53	0.278	-0.316	6.11	440.83	46.79	0.506	0.128
Image5	83.08	78	32.72	0.428	0.164	6.44	456.70	50.27	0.898	0.189
Image6	92.73	80	63.99	0.469	0.732	5.29	466.79	41.93	0.463	0.113
Image7	81.02	94	69.55	0.649	0.636	6.32	415.43	37.26	0.805	0.302
Image8	78.98	86	57.07	0.312	-0.62	6.13	389.26	29.13	0.477	0.132
Image9	84.55	112	61.47	0.441	0.727	5.69	424.67	38.21	0.399	0.078
Image10	82.61	89	58.28	0.611	0.676	5.48	411.08	26.04	0.662	0.160

Table 2: Statistical and Morphological Parameters of Abnormal UBM Images

Images	Mean	Median	S.D.	Skewness	Kurtosis	Iris Area (in mm^2)	Iris Perimeter (in mm)	Angle (in deg)	AOD _500 (mm)	ARA _500 (mm^2)
Image1	93.58	92	29.42	0.193	0.613	4.721	421.35	24.63	0.105	0.026
Image2	94.72	95	31.23	-0.202	0.031	4.204	392.69	28.62	0.131	0.032
Image3	191.1	198	43.9	-1.029	1.109	2.682	409.34	25.98	0.221	0.035
Image4	139.6	136	31.92	0.396	0.63	2.191	326.16	20.43	0.255	0.071
Image5	91.89	96	42.09	-0.298	-0.351	4.668	331.16	18.81	0.227	0.054
Image6	93.36	107	80.9	0.347	0.581	2.405	375.28	26.46	0.370	0.171
Image7	80.54	125	45.59	0.577	-0.779	2.586	363.05	22.76	0.282	0.077
Image8	82.7	88	48.29	0.521	0.748	4.109	402.47	25.61	0.393	0.162
Image9	94.75	73	27.64	-0.736	0.109	2.649	355.44	16.83	0.386	0.121
Image10	84.94	111	34.16	0.632	0.531	3.104	360.57	27.29	0.176	0.059

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In this work, the UBM images were preprocessed by despeckling with linear filter and iris region was selected as region of interest for which statistical and morphological parameters were analyzed. AOD and ARA are considered the key important morphological parameters as they are one among the angle parameters, established by Pavlin, which are to be evaluated so that the blockage of drainage channel can be diagnosed. The values of these parameters were classified using the linear SVM classifier for classifying the normal and abnormal UBM images and the actual and predicted values were measured, thereby analysing the performance of the classifier as shown below in the figure 2.

The overall accuracy, specificity and sensitivity were 95%, 100% and 90.9% respectively when run on a dataset of 20 images. From this, it is found that the linear SVM classifier gives good success percentage in classifying the normal and abnormal UBM images.

Future Scope

In future, this work can be extended for detection of presence of glaucoma and classification of normal and abnormal images for above 20 UBM images which would provide efficient results for accurate diagnosis of glaucoma. In certain cases, the blockage of aqueous fluid occurs in the area of lens contact with the iris resulting in glaucoma. The parameters considered in this work gives no indication about this obstruction and so two parameters namely Iris Lens Angle (ILA) and Iris Lens Contact Distance can be considered in future as they give information about the blockage of aqueous fluid near the lens area.

Ethical Clearance: The Study is based on the Digital Processing of the sensor and its connectivity via IoT (Internet of Things). The Study is been conducted by the guidance of Head of the Department, Ms.R.J.Hemalatha.

This Study does not require Ethical Clearance. This Study is conducted in the Biomedical Instrumentation Lab of Vels Institute of Science Technology and Advanced Studies – Department of Biomedical Engineering, Chennai -117.

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Conflict of Interest: Nil

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