Automated Classification of Normal, Cataract and Post Cataract Optical Eye Images using SVM Classifier

Jagadish Nayak

***Abstract*— Eye is a very important organ of the human body, which has many complex sensory elements such as lens, retina etc. Eye disorder is a prominent issue in the health care sector. Cataract is an eye disorder, which occurs due to the clouding of lens. Over a period of time, cataract will lead to reduced eyesight. If cataract is not treated in proper time, then it will lead to blindness. This is common in aged people. In this work image processing techniques are used to detect the features in the three classes of optical eye images such as normal, cataract and post-cataract images. The features of the optical eye image such as Big Ring Area (BRA), Small Ring Area (SRA), Edge Pixel Count (EPC) and Object Perimeter are extracted. The features are statistically analyzed and found to be significant for the automatic classification. The same features are then used in the automatic classifier such as Support Vector Machines (SVM) for the automatic classification. The results are found to be clinically significant with 94% sensitivity and 93.75% specificity. The classification rate is nearly 90%.**

Index Terms- Cataract, Eye disorder, Big Ring Area (BRA), Small Ring Area (SRA), Edge Pixel Count (EPC) and Object Perimeter, SVM

I. Introduction

The research on medical images has been adopted by most of the scientists and physicians, which can assist in the detection of the abnormalities. The image processing algorithms are developed to identify the disease specific features on the medical images, which can help in the detailed study of abnormalities. The cataract is an eye disorder, which is basically detected by looking at the lens of the human eye. The anatomical changes occurred in the lens due to the abnormality is one of the decision factors for the detection of cataract. Computer processing of a medical image such as optical eye image can provide us with objective measure of the symptoms of the cataract. These objective features can be the decision factor for the abnormality detection. Pattern recognition systems can be used for the automated detection of eye abnormality using this feature vector.

Manuscript received February 23, 2013;
Jagadish Nayak is with the BITS PILANI Dubai, Dubai International Acedemic City , Dubai, phone: +971 55 4907979 e-mail: jagadishnayak@ dubai.pilani-ac.in.

Fig. 1 shows the complete system for the automated classification of three classes of optical images such as normal, cataract and post cataract.

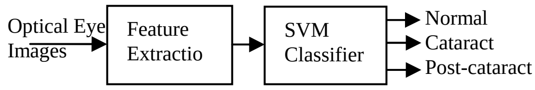
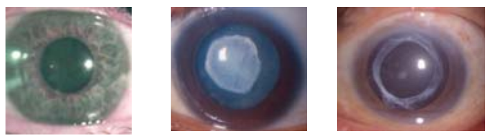


Figure 1. Proposed system for the automated classification of optical eye images

The normal eye [1,2,3,4] is made up of the sclera, cornea, pupil, aqueous humor, iris, conjunctiva, lens, vitreous humor, ciliary body, macula, retina, fovea and the optic verve. Lens is the clear part of the eye behind the iris that helps to focus light on the retina. The lens helps to focus on both far and near objects so that they are perceived clearly and sharply. The ciliary muscle helps to change the shape of the lens. This changing of the lens shape is called accommodation. It is said that the diameter of the lens is 10mm. Fig. 2(a) shows the optical image of a typical normal eye.

A cataract is a clouding of the natural lens, which lies behind the iris and the pupil. The lens is contained in a sealed bag or capsule. Fig. 2(b) shows the image of the eye affected with cataract. The main symptom is gradual, painless vision blurring. As old cells die they become trapped within the capsule. Over time, the cells accumulate causing the lens to cloud, making images look blurred. Cataracts generally develop slowly over years. Early symptoms may be loss of contrast, glare, needing more light to see well, and problems distinguishing dark blue from black. Later, progressive, painless blurring of vision occurs.[1,2,3,4].

When the cataracts have progressed enough to seriously impair the vision and affects daily life, the cataract surgery is necessary. Cataract surgery is simple and relatively painless procedure to regain vision. Cataract surgery is very successful in restoring vision. During surgery, the surgeon will remove the clouded lens , and in most cases replace it with a clear ,plastic intraocular lens (IOL). Fig 2(c) shows the optical image of post cataract eye.[1,2,3,4]



(a) (b) (c)

Fig. 2. Optical Images
(a) Normal (b) cataract (c) Post-cataract

ISBN: 978-988-19252-3-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

In 1989 , Nuclear Magnetic Resonance (NMR) microscopic imaging method is used to detect the early stages of cataract, but this method is limited by the resolution problem[5]. Wong *et al*, have studied the galactose cataract using a conventional whole-body Magnetic Resonance Imaging (MRI) operated at 0.6 Tesla [6]. The optical aberrations caused by cataract were detected and quantified objectively using a new system called focus detection system (FDS) [7]. Monestam *et al*, have compared the functional outcome of cataract surgery in terms of visual ability between patients younger than 84 years, 85 to 89 years, and 90+ years [8]. Best corrected visual acuity (BCVA), contrast sensitivity (CS) and functional visual complaints in early cataract and after the cataract surgery were examined [9]. Ferraro *et al*, have assessed the validity of a digital non-mydriatic fundus camera in detecting cataract as a cause of visual impairment [10]. They showed that the non-mydriatic fundus camera may be an alternative method for screening for visually significant cataract in the community. An early transvaginal anomaly scan at 14-16 gestational weeks has been proposed to diagnose fetal eye anomalies (especially cataract) using ultrasound [11]. Specifically, using the Ultrasonography technique, cataract was detected in the foetus in more than 80% of the cases. A novel method for the automated classification of normal, cataract and post-cataract optical images is presented in this paper. Details of the algorithm development and implementation is shown in Section II, results are given in section III, discussion is given in section IV and conclusion is given in section V.

II. MATERIALS AND METHOD

The optical images were collected from Kasturba Medical College, Manipal, India. Total of 174 images of all the age group (both male and female) is collected. Out of those 56 images are normal, 89 images are of cataract images and 29 post-cataract images. All the images are of size 128x128, stored in the TIFF format.

A. Image Preprocessing

Usually, there is a large variation in the color of eye images among the patients. This variation is strongly correlated to the person's skin pigmentation and iris color. Hence, it is mandatory to identify a reference frame and normalize the colors of all other images against it. One reference eye image is selected from the dataset and colors of all other images in the dataset are normalized in accordance with the reference image [12]. The contrast of the eye images are not distributed evenly throughout the image. The objective of this preprocessing was to reduce this effect and to normalize the mean intensity. The intensities of the three color bands were transformed to an intensity-hue-saturation representation [13]. This allowed the intensity to be processed without affecting the perceived relative color values of the pixels.

B. Detection of Small Ring Area

The color at the inner surface of the cornea is not the same in all the three kinds of images. In cataract images the inner surface of the cornea images is more whitish as compared to that of normal and post-cataract images. The pictorial representation of SRA is given by the template as shown in Figure 3. It is the region between C_i and C_o with r_o=5 and r_i= 15 in this work. Fig. 4(a), (b), and (c) shows the results of computing SRA in normal, cataract and post cataract images of different subjects respectively.

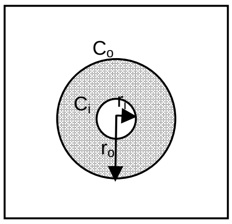
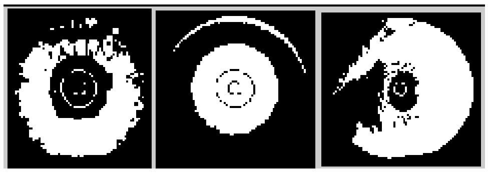


Fig. 3 Template for small ring area detection



(a) (b) (c)

Fig. 4. Small ring area detection in (a) normal (b) cataract (c) pos-cataract images for different subjects

C. Detection of Big Ring Area

The color at the outer surface of the cornea is not the same in all the three classes. In cataract images, the outer surface of the cornea images is bright in color as compared to that of the normal and Post-cataract images. The pictorial representation of BRA is given by the template as shown in Fig. 5. It consists of two circles: an inner circle C_i and an outer circle C_o. In this work, the region between the C_i and C_o is the BRA with r_o= 59 and r_i= 55. Fig. 6(a), (b), and (c) shows the schematic diagram of the BRA detection for normal, cataract and Post-cataract images of different subjects respectively.

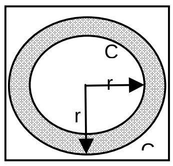
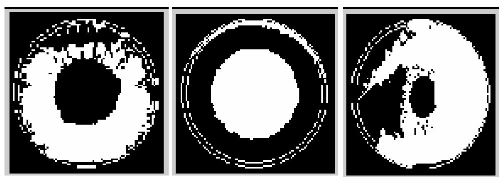


Fig. 5. Template for big ring area detection



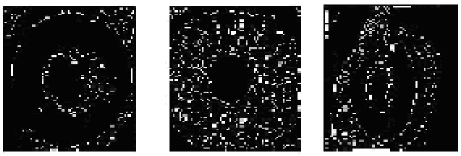
(a) (b) (c)

Fig. 6. Big Ring Area detection in (a) normal (b) cataract (c) pos-cataract images for different subjects

ISBN: 978-988-19252-3-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

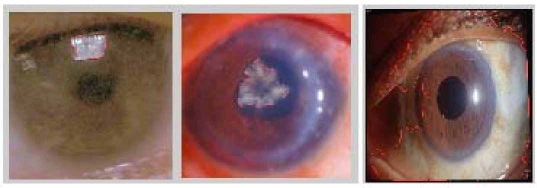
D. Edge pixel count (EPC)

There are different methods available to extract the edges of the eye images namely: sobel, canny, prewitt, roberts, log, etc. Canny method is the most powerful edge-detection method among them. It uses two different thresholds (to detect strong and weak edges), and it includes the weak edges in the output only if they are connected to strong edges. In the computation of EPC, we counted the number of white pixels in the output of the edge detection. Fig. 7 shows the three class of eye images with EPC detected.


(a) (b) (c)
Fig. 7 Edge pixel count in (a) normal (b) cataract (c) Post cataract subjects

E. Object Perimeter

Morphological image processing is a type of processing in which the spatial form or structure of objects within an image is modified. Dilation, erosion and skeletonization are the three fundamental morphological operations. With dilation, an object grows uniformly in spatial extent, whereas with erosion an object shrinks uniformly. Skeletonization results in a stick figure representation of an object. The *normal*, *cataract* and *post-cataract* images have too many sudden changes in the gray levels. Hence, there will be many edges in these images which can be used as a feature to reflect normality and abnormalities in the eye images. There are many different types of morphological operations available, however; in this case, the best result obtained was from using an operation called erosion. Erosion is performed using the structuring element of size (3x3) with all ones. Fig. 8 shows the object perimeter of the eye images of the three classes specified in this work.


(a) (b) (c)
Fig. 8 Object Perimeter (a) normal (b) cataract (c) Post cataract subjects.

F. Support Vector Machine (SVM) Classifier

SVMs are new type of pattern classifier based on a novel statistical learning technique that has been recently proposed by Vapnik et al [14]. Unlike traditional methods (eg. Neural Networks), which minimize the empirical training error, SVMs aim at minimizing an upper bound of the generalization error through maximizing the margin between the separating hyperplanes and the data [15]. SVMs are known to generalize well even in high dimensional spaces under small training samples conditions. They have been proven to be superior as compared to the traditional empirical risk minimization principle employed in most of neural networks. SVMs have been successfully applied in various fields like classification, regression etc [16].

III. RESULTS

Table I shows the range of four features used for the classifications. It can be seen from the table that these features show very low ‘p-value’ ($p<0.0001$) indicating that they are clinically significant. Table II shows the classification results of the two classifiers. We used 125 eye images for training and 49 features for testing. Our result shows that we are able to detect the early stage of cataract and classify normal, cataract and post-cataract eye images with an average accuracy of 88.39%. The SVM classifier is able to identify the (average) correct class to the tune of 88%. It is able to classify almost all the cataract and normal eye images correctly.

The sensitivity of a test is the proportion of people with the disease who have a positive test result. Higher the sensitivity, greater will be the detection rate and the lower the false negative (FN) rate. The specificity of the test is the proportion of people without the disease who have a negative test. Higher the specificity, lower will be the false positive rate and the lower the proportion of people with the disease who will be unnecessarily worried or exposed to unnecessary treatment. The MedCalc statistical software [17] was used for analysis. As we can see from the Table III that our system has the sensitivity of 94% and specificity of 93.75% for all the classes indicating that the results are clinically significant.

TABLE I

RANGES OF DIFFERENT PARAMETERS FOR NORMAL, CATARACT AND POST- CATARACT EYE CLASSES.

Features	Normal	Cataract	Post Cataract	p value
Big Ring Area	709.41 ± 211	716.88 ±178	491 ±242	p < 0.0001
Small Ring Area	277.75 ±240	336.30 ±219	153.97 ±231	p< 0.0053
EPC	9137.3 ±1858	8435.2 ±2831	6276.0±1433	p< 0.0001
Perimeter	295.16 ±272	464.42 ±214	596.52 ±371	p< 0.0001

TABLE II
NUMBER OF TRAINING, TESTING DATA (FEATURES) AND PERCENTAGE OF CORRECT CLASSIFICATION.

Classifier	TN	TP	FP	FN	Sensitivity (%)	Specificity (%)
SVM	15	31	01	02	94	93.75

ISBN: 978-988-19252-3-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

TABLE III

RESULTS OF SENSITIVITY, SPECIFICITY FOR COMPLETE EYE CLASSES SVM CLASSIFIERS

Type of Image	**No. of Training Samples**	**No. of Test Samples**	**SVM Classifier**	
			No. of samples correctly classified	**% Result**
Normal	40	16	15	93.75
Cataract	63	26	26	100
Post-Cataract	22	07	05	71.42

IV. DISCUSSION

In our work, *cataract* eye can be identified with 100% accuracy. With the inclusion of more cataract images at the early stages, the proposed system can be made more robust to identify cataract at the early stage too. The *post-cataract* eye images have been used to test the efficacy of cataract operations. The accuracy of the system can further be improved by increasing the size and quality of the training set. The classification results can be enhanced by extracting additional features from the optical images. Environmental conditions such as the reflection of light influences the quality of the optical images and hence, the efficiency of classification. The software for feature extraction and the program for classification of eye images are written in MATLAB 7.0.4.

V. CONCLUSION

In this paper, we have discussed the performances of SVM classifier as diagnostic tools to aid physicians in the detection of cataract even at the early stages. These classifiers are also suitable for diagnosing the effectiveness of cataract operations using the post-catact images. However, these tools generally do not yield results with 100% accuracy. The accuracy of these tools depend on several factors such as the size and quality of the training set, the rigor of the training imparted, and parameters chosen to represent the input. From the results obtained as listed in Table II and III, it is evident that the SVM classifier is effective to the tune of about 88% accuracy.

ACKNOWLEDGMENT

The authors wish to thank Head of Ophthalmology department, Kasturba Medical College, Manipal, INDIA, for providing images and clinical support required for this work.

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