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A Survey on Computer-Aided Healthcare Diagnosis for Automatic Classification and Grading of Cataract

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***Abstract* - A fundus image analysis based computer aided diagnosis for automatic classification and grading of cataract is presented.The burden of ophthalmologists can be reduced due to this system and help cataract patients to know their cataract conditions. The system comprises the processes as pre-processing of fundus image, image feature extraction and automatic cataract classification and grading. A multiclass discriminant analysis algorithm is used for cataract classification, including two-class classification and cataract grading in mild, moderate, and severe. The wavelet transform is investigated to extract from fundus image. ANN based methods and SVM based methods have been used in pattern recognition and classification. The fundus image analysis for cataract classification and grading is very helpful for improving ophthalmic healthcare quality and review of fundus image.**

Keywords - Pre-Processing; feature extraction; cataract classification and grading; ANN; SVM.

I. INTRODUCTION

The disease cataract is a clouding and dulling of the eye lens. It leads to decrease in vision. The eye lens focuses an image onto the retina of the eye. This is where that image can be processed, and then sent to the brain. The decreased vision, glare, contrast, color sensitivity and sometimes blindness can happen when cataract matures.

The only way to diagnose the cataract includes examining the eyes of the patient. The eye doctor will examine the lens of eye or do some tests to know more about the health and structure of the patient's eye.

The comprehensive eye examination for cataracts commonly comprises:

- Visual acuity assessment test (VAT) for assessing distant vision.
- Slit lamp examination for magnify the eye.
- Tonometry test for assess fluid pressures happenings inside the eye and the increased pressure may leads to glaucoma disease.
- Dilated eye examination for evaluating the lens and the structures of the back of the eye.
- Other Treatments

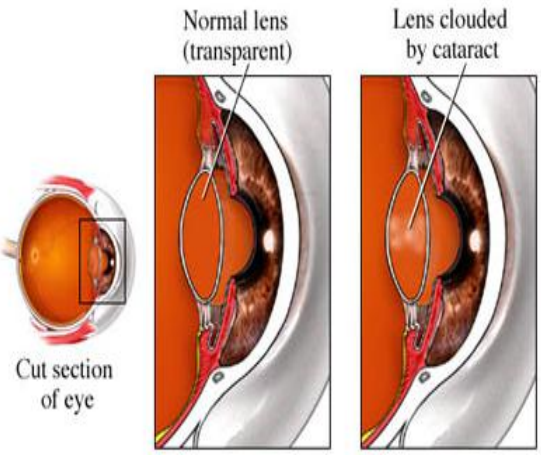

Fig. 1: Cross Section of Eye

For an earlier stage of cataract, the vision may be improved by using different eyeglasses, magnifying lenses, or stronger lighting. If these measures do not help, or if vision losses interfere with daily activities such as driving, reading, or watching TV, cataract surgery is the one of the efficient treatment. The cataract surgery involves waiting until the patients are ready to have it so that it does not harm the patient's eye. While the patient takes long time for surgery, cataract will get cloudier with time. This type of surgery is almost performed always in one eye at a time. After the cloudy presence in lens is removed, the eye surgeon places an intraocular lens in its place. An intraocular lens is a lens which is clear which does not require care and becomes a mandatory part of eye. Most people need reading glasses or glasses for distance vision, which is still problematic after surgery. There is another new option that is multifocal intraocular lenses, which is suitable for both near and far distances in the particular lens. Many who receive multifocal intraocular lenses may not need to wear any type of glasses.

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II. COMPUTER-AIDED DIAGNOSIS (CAD)

In medical imaging and diagnostic radiology, Computer Aided Diagnosis (CAD) is one of the key research topics. The philosophy and motivation for early improvement of CAD schemes are presented together with the present status and future potential of CAD in a PACS environment. Radiologists use the computer results as a second option and make the final decisions based on the CAD. This is a concept established by taking equal roles of surgeons and processors, whereas automated computer diagnosis is a concept based only on computer algorithms. With CAD, the performance of computers better than that by or does not have to be comparable to physicians, but needs to be corresponding to that by surgeons. In fact, in the detection of breast cancers, a large number of CAD systems have been employed for supporting physicians.

A Computer Aided Diagnosis scheme that makes use of lateral chest images which comprises the potential to improve the overall efficiency in the detection of lung nodules when combined with other CAD scheme for chest images. On lateral chest radiographs, vertebral fractures can be reliably detected by computer, thus radiologist's exactness in the detection of vertebral fractures would be improved by using CAD feature, and further diagnosis of osteoporosis would become possible in earlier stage. In MRA for assisting those radiologists in the detection of intracranial aneurysms, a CAD system has been introduced. A CAD scheme for detection of interval changes has been developed by use of sequential subtraction images for consecutive bone scan images. In the future, many CAD schemes could be accumulated as packages and executed as a division of PACS. For example, the chest CAD package may include the computerized detection of interstitial opacities, lung nodules, vertebral fractures, cardiomegaly and interval changes in chest radiographs as well as the on-screen categorization of caring and malignant lumps and the differential diagnosis of interstitial diseases on lungs. In demand to assist in the differential diagnosis, it is possible to search for images and retrieve images with known pathology and would be much related to a new unidentified case, from PACS when a reliable and useful method has been implemented for checking the similarity of a pair of images by radiologists for visual comparison.

Recently, computer-aided diagnosis (CAD) becomes a measure of the tedious clinical work for detection of breast cancer at many screening locations and hospitals. This appears to indicate that CAD is the beginning to be applied widely in the recognition and variance diagnosis of many different types of irregularities in medical images in numerous examinations by use of different imaging modalities is acquired. In detail, CAD developed as one of the major research topics in medical imaging and diagnostic radiology. Although early attempts in computerized analysis of medical images were created in the 1960s, systematic and serious research on CAD initiated in the 1980s with an essential change in the concept for deployment of the computer output, from automated computer diagnosis to automatic Computer-Aided Diagnosis. The philosophy and motivation for early progress of CAD schemes are presented together with the present status and future potential of CAD in the Picture Archiving and Communication Systems (PACS) environment.

III. FUNDUS IMAGES OF CATARACT

The fundus of the eye is the interior portion of the eye, opposite the lens and includes the optic disc, retina, fovea macula and posterior pole. The fundus can be examined by either ophthalmoscopy or fundus photography.

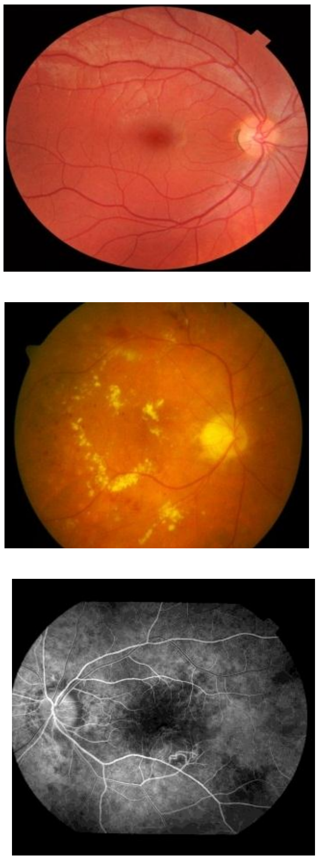

Fig. 2: Fundus images of eye

The different categories of cataracts include:

- A **subcapsular cataract -** This arises at the back portion of the lens. Greater risk of emerging a subcapsular cataract comprises the people with diabetes or the people who takes high doses of steroid medicines.
- A **nuclear cataract -** It is made on the depth of the nucleus of the lens. This nuclear cataract usually related with aging.
- A **cortical cataract -** It is characterized by wedge-like, white opaqueness that start in the periphery of the lens and it work their way to the center in a spoke-like fashion. This type of cataract mainly arises in the lens cortex, which is the part of the lens that surrounds the central nucleus.

Cataracts may be stationary or progressive, partial or complete, or hard or soft. The main categories of age related cataracts are cortical, nuclear sclerosis, and posterior subcapsular.

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Nuclear sclerosis is the most common kind of cataract, which involves the central or nuclear part of the lens. Over period, this becomes hard or 'sclerotic' due to deposition of brown pigment within the lens and condensation of lens nucleus. In progressive stages, it is said to be known as brunescent cataract. These types of cataract can exist with a shift to shortsightedness and causes difficulties with distance vision and reading is less affected.

Cortical cataracts are due to the lens cortex that is outer layer becoming opaque. They happen when changes in the water content of the boundary of the lens causes fissuring. When these cataracts are observed through an ophthalmoscope or other magnification method, the presence is related to white spokes of a wheel. Symptoms often include difficulties with glare and light scatter at night.

Posterior subcapsular cataracts are cloudy at back of the lens contiguous to the capsule in which the lens lies. Because light becomes more engrossed toward the back of the lens, they can cause uneven symptoms for their size.

An undeveloped cataract has certain transparent protein, but with a mature cataract, the entire lens is cloudy. In a hyper mature or Morgagnian cataract, the lens proteins have become liquefied. Congenital cataract, which may be identified in middle age, has a different cataloging and includes lamellar, polar, and sutural cataracts.

IV. METHODS

The present cataract examination equipment and techniques, such as Lens Opacities Classification System (LOCS) [16], are difficult for most patients and can only be operated by well-experienced ophthalmologists. To make them appropriate to accomplish a diagnosis based on fundus image of eye, the well-experienced ophthalmologist has to be substantially close to the patients. This statistic makes the ophthalmologist becoming a limited resource and a bottleneck that causes the large scale screening in the early stage of the cataract disease unmanageable. The fundus image can be more effortlessly obtained only with the help of nurses from public service even the patients themselves.

This system emphasis on the analysis of fundus image and fully automatic classification of cataract. Its goal is to decrease the problem of scarce resources and improve the usefulness and proficiency of fundus image review, through which to facilitate active and superior healthcare services.

The basic requirement is to develop a cost-effective and convenient computer-aided auxiliary analysis system for classification and grading of cataract automatically, which should sort multiple types of healthcare facility providers loosely coupled together and cooperatively provide high quality medical precaution to the patients in rural regions. Consequently, cataract classification and grading system is designed. The main component of the system consists of three parts which includes pre-processing of fundus image, feature extraction, and automatic classification and grading of cataract. These three measures will run on the server of an ophthalmic clinic and can be incorporated into its prevailing information systems.

The existing information system has collaborated with many public clinics, remote pastoral hospitals and additional hospitals, sharing the healthcare resources through the internet. This co-operative mode has greatly enriched the medical service quality and clinic proficiency. The proposed cataract classification and grading system recovers fundus image of eyes from the server, conducts analyses of images and automatic cataract classification, and yields the report on the classification results.

In this way, the automatically grading and classification system replaces the manual screening and decouple the co-located association between patients and well experienced ophthalmologists. Since the non-cataract eye images are not directed to the ophthalmologist for testing, a large amount of work burden of scarce resources is shortened, which make them be capable to expend more time on the patients that really need their concerns. Inside our structure, each fundus image of eye is converted into a set of types after pre-processing and feature extraction, based on which consequences are obtained by classification algorithm. The outcome gives the ophthalmologist a reference to the condition of cataracts patients.

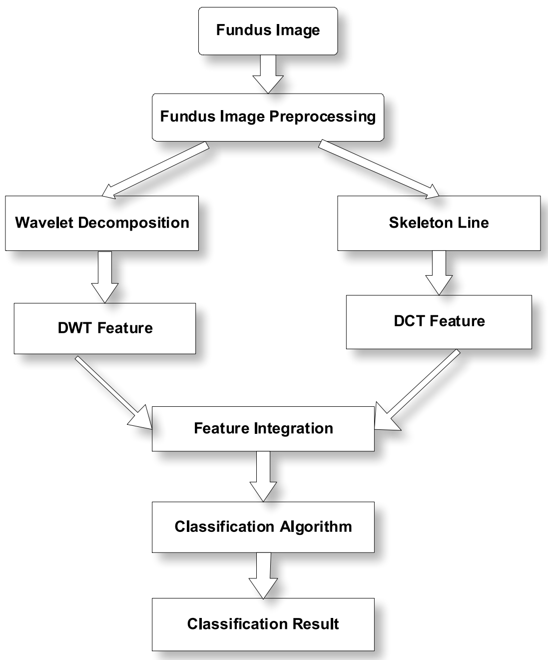

Fig. 3: Overall Structure

A. Fundus Image Preprocessing

It involves the preprocessing of fundus images to remove noise and to correct non-uniform illuminations. An appropriate preprocessing will yield an accurate result in the further stage. In this module first we will load the original input fundus image. Then Gaussian filter will be applied for input fundus image to get an original image without noises.

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B. Image Feature Extraction

When the input image to an algorithm is processed and it is supposed to be redundant then it can be renovated into a reduced set of features. In this module, feature extraction is done by Wavelet Transform. A wavelet transform is the demonstration of a function by wavelets. The wavelets are scaled and converted copies, said to be known as daughter wavelets, of a fast-decaying or finite length oscillating waveform, known as the parent wavelet. Wavelet transforms have benefits over traditional Fourier transforms for expressive functions that have cutoffs and sharp peaks, and for exactly disintegrating and recreating finite, non-periodic and non-static signals.

Wavelet Transforms are categorized into two transformations as Discrete Wavelet Transforms (DWTs) and Continuous Wavelet Transforms (CWTs). Both the transforms are continuous-time analog transforms. CWTs operate over each potential scale and translation whereas DWTs practice an exact subclass of scale and translation ideals or representation grid. In this, Discrete Wavelet Transform is used.

Due to the advantage of improved resolution, the Gaussian wavelets are chosen as parent wavelet. The wavelet transform 2D-DWT is used to find its spectral components and its features which are of 64x64 matrix are extracted from the obtained 2D-DWT representation.

a. Discrete Wavelet Transform

This type of transformation decomposes an image into several sub-bands according to some recursive process

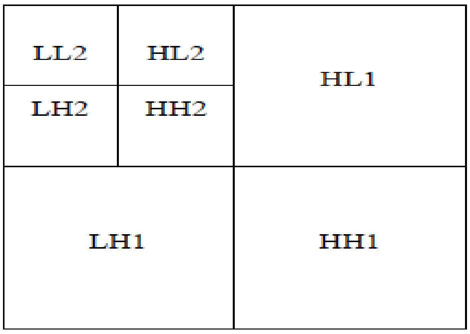

Fig. 4: Two level 2-D DWT decomposition

Fig. 4 comprises of LH1, HH1 and HL1 which represents the detailed images and LL1 corresponds to the estimate image. The estimate and detailed images are then decomposed into second-level approximation with detailed images, and the process is iterated to achieve the preferred level of the analysis of multi-resolution. The managed coefficient values for the approximation and detail sub-band images are useful features for texture classification. Due to the advantage of better resolution, the Gaussian wavelet is chosen as parent wavelet. The wavelet transform 2D-DWT is used to find its spectral components and its features which are of 64x64 matrix are extracted from the obtained 2D-DWT representation.

Related Works

Luo Gang *et al.*, [9] paper deals with that Gaussian function which is evaluated and an amplitude-modified second-order Gaussian filter is proposed for the recognition and measurement of blood vessels.

Mathematical analysis is given and sustained by a simulation and experiments to determine that the width of vessel can be dignified in linear relationship with the spreading factor of the coordinated filter after the filter's magnitude coefficient is appropriately assigned. The absolute value of diameter of the vessels can be determined basically by using a pre-calibrated line, which is typically necessary since images are constantly system dependent.

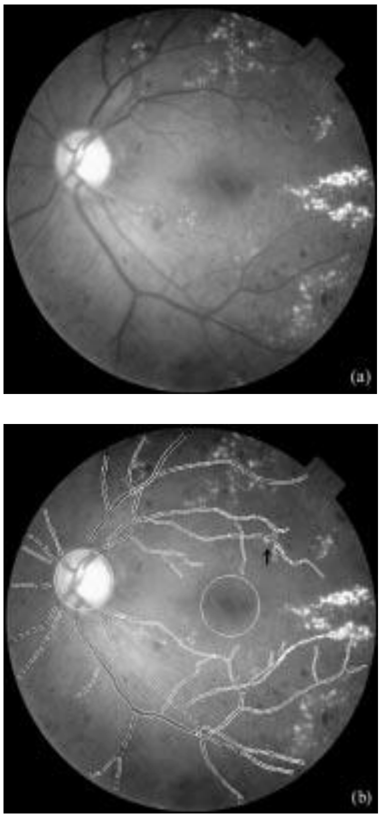

Fig. 5: Applications of second-order Gaussian filter for retinal vessel detection. (a) Green component of color fundus image. (b) Detecting and quantifying results.

C. Automatic Cataract Classification And Grading

The proposed system of cataract classification and grading retrieves the fundus image from the server, ways image analysis and automatic cataract classification, and yields the report on the classification results. In this way, the automatic grading and classification system interchanges the manual screening and decouple the co-located association between patients and well-experienced ophthalmologists. Since the non-cataract images are not directed to the ophthalmologist for testing, a huge amount of work burden of scarce resources is reduced. After feature extraction, the algorithm of multiclass discriminant analysis is used for cataract classification, including two-class classification and cataract grading in mild, moderate, and severe.

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Related Works

C. Sinthanayothin, et al., [10] paper compacts with the approaches of automatic recognition and location. The optic discs were located by identifying the part with the highest difference in intensity of neighboring pixels. Blood vessels were acknowledged by means of a multilayer perceptron neural net, for which the responses were resultant from a Principal Component Analysis (PCA) of the image and detection of edge of the first component of PCA. The foveas were recognized together with characteristics typical of a fovea using matching correlation.

Fig. 6: A sample images of recognition of the main components of the fundus image

D. *Performance Evaluation*

Following the feature extraction approaches, a multi-class discriminant analysis is used for classification and grading of cataract. The algorithm of multi-Fisher classification is trained by randomly selecting some samples from the data set and then tested by using the other samples. By repeating the training and testing procedure, the overall performance of the aforementioned classification and grading methods are obtained.

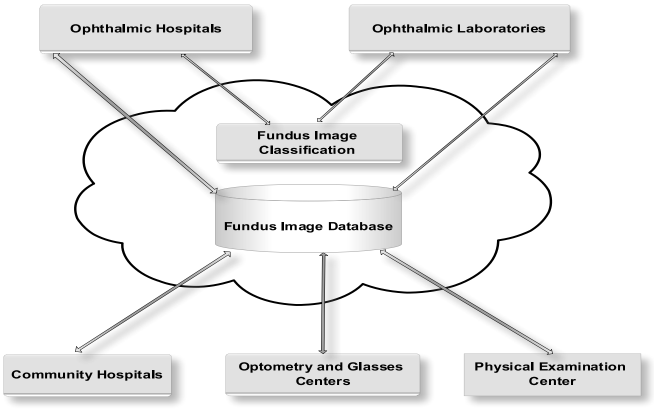

Fig. 7: Real-world application of our proposed algorithm on fundus image classification

V. RESULT AND ANALYSIS

In this Section, we explained sample result which was obtained by using Gaussian Filter method. The input fundus image is given and preprocesses the image based on the discrete wavelet transformation. The sample screen shots are shown in Fig. 8 to 12. The following figure explains the sample result for smoothening, segmentation of blood vessels, the enhanced image of optic disk and image segmentation results.

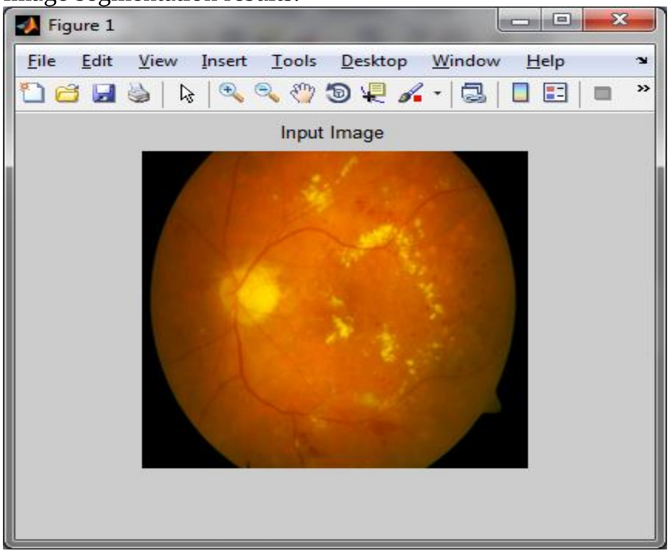

Fig. 8: Input Fundus Image

Fig. 8 shows the sample fundus image which is used for preprocessing, extraction and classification of the cataract. The cataract can be identified by analyzing optic disk, blood vessel, macula and lobs of each fundus image.

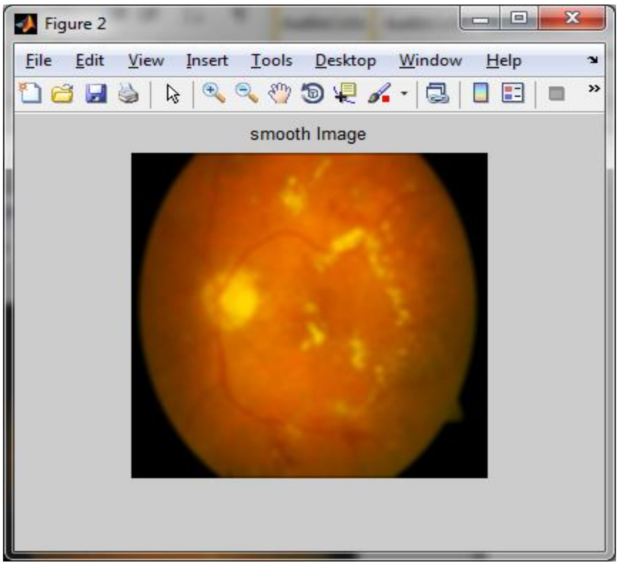

Fig. 9: Smoothen Image

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In Fig. 9, the smoothened image is displayed. In which the data is to create the function that works to capture important patterns in the image. Mainly smoothening method is used in scale space demonstrations.

Fig. 10: Green channel image

In Fig. 10, the green channel component of a fundus image is shown. The green component image increases the contrast of shape borders to improve the acutance and apparent sharpness of the macula and the blood vessels.

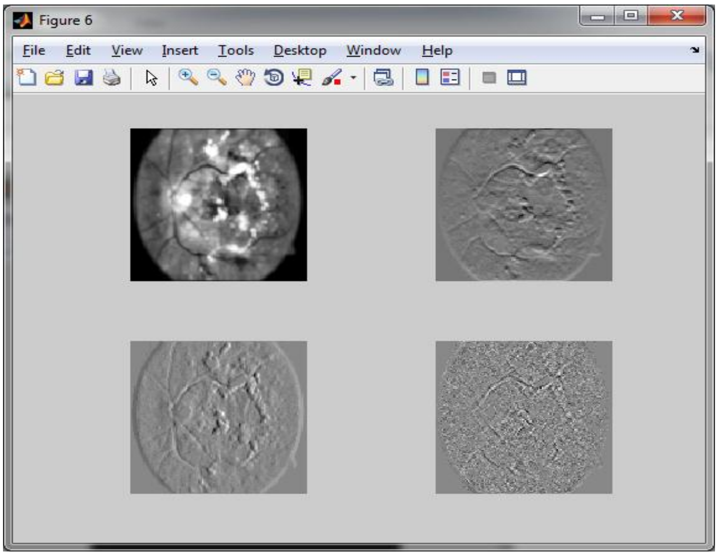

Fig. 11: Contrast Enhanced Image

Fig. 11 shows the contrast enhanced image of the given fundus image of eye. Contrast enhancement of color images is typically done by transforming an image to a color space that has image intensity as one of its components. Contrast enhanced image prevent the over saturation caused by basic histogram equalization.

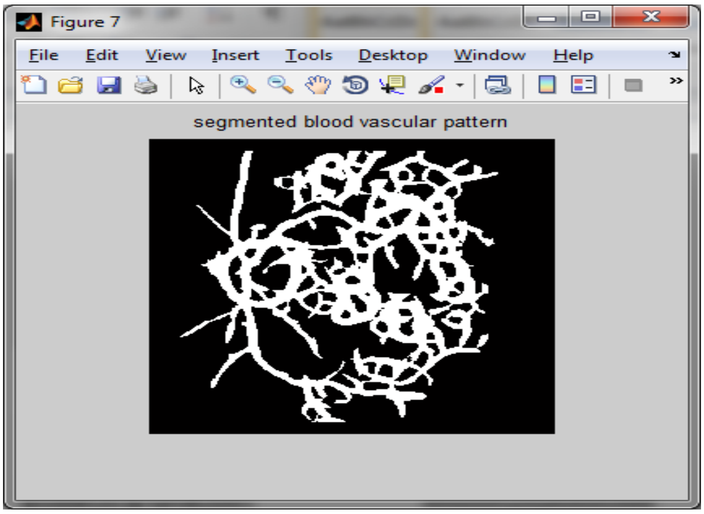

Fig. 12: Segmentation of Blood Vessels

Fig. 12 displays the blood vascular segmentation of fundus image. The segmentation of blood vessels is also an important step for the detection of bright and dark lesions, the performance of automatic detection methods may be enhanced if regions containing vessels can be excluded from the analysis.

VI. CONCLUSION

A computer-aided healthcare diagnosis system for cataract classification and grading from fundus image is presented. The wavelets transform method with discrete cosine transformation is used to extract the features in fundus image. The preliminary test results on a data set of fundus image samples show that the performance of the wavelet transformation based method is efficient than that of the sketch based method. The real-world pilot study about the execution and organization of the automatic classification system of fundus image is described. By retrieving fundus image of eye from the Cloud server, conducting analysis of fundus image and automatic classification of cataract, and return the report on the organization results, the proposed solution offer great abilities to reduce the burden of the well-experienced ophthalmologists having the scarce resources and improve the quality of ophthalmic healthcare.

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