AUTOMATED DETECTION OF RETINAL DEFECTS USING IMAGE MINING- A REVIEW

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ABSTRACT
World Health Organization (WHO) in a recent study has identified eye related defects to be one of the primary health challenges faced by the current society. Retinal eye defects have significantly increased in the last decade across developing and developed countries. Early diagnosis of these defects can help reduce the progression of eye defects. With recent advances in the field of image processing and data science, automated detection of retinal abnormalities has made diagnosis cost effective and efficient. This paper discusses the different methodologies adopted for automatic detection and gives insight into the progression of image mining techniques.

KEYWORDS: Retinal abnormalities, Glaucoma, Diabetic retinopathy, Fundus images, Feature detection, Segmentation, Optic disc, Optic cup, KNN, Naive-bayes, SVM.

INTRODUCTION
WHO has highlighted in a recent study that 285 million people with visual impairments either in the form of blindness or visual impairment. This amounts to 10% of the total world population. This stresses the need for cost effective, faster techniques to identify such deficiencies and address them at an early phase. Retinal abnormalities are currently common critical issues faced by people across different strata of the society. Common retinal abnormalities include Glaucoma, Diabetic retinopathy and Macular degeneration. These defects if not diagnosed and treated at the appropriate time, would result in complete loss of vision. Many of the most recent treatments for these ailments include reduction in progression of the defect rather than a complete cure of the abnormality. In many cases, it is noticed that these defects go unnoticed as they are symptom free and substantial loss of vision occurs even before the actual diagnosis.

Retina is a critical part of the eye enabling conversion of light to neural signals to enable the brain for visual recognition. Retina requires sufficient and constant supply of blood through network of tiny blood vessels for proper functioning. Diabetic retinopathy is predominantly common among diabetic patients. As the blood sugar level increases, the blood vessels in the retina are damaged. The blood vessels swell, leak or close eventually stopping the flow of blood to the retina.

Macular Degeneration is the deterioration of the central portion of the retina. In this case, the retinal cells deteriorate and images are not received correctly. Glaucoma is a chronic visual impairment which leads to loss in vision. It is generally characterized by degeneration of optic nerves. The general perception is that glaucoma is caused by increased pressure in the eye. The elevated pressure is caused by the impaired drainage of fluid (aqueous humor) in the eye. The normal eye pressure is between 14mm Hg and 20mm Hg.

Most of these defects are gradual and hence identification of defects at an early stage becomes a significant challenge. While vision damage cannot be cured, the progression of these abnormalities can be slowed down with medication. With the growth of population and reduction in doctor to patient ratio, it is necessary to develop cost effective automated methodologies that enable faster / earlier diagnosis. Recent advancements in the field of Image Processing and Data Science have helped automated diagnosis of many eye related defects.

Image processing is the transformation of an image, which is a 2-dimentional signal, f(x,y) (where x and y represent the amplitude and intensity of the image) through data processing. For processing, the image is converted to digital form using sampling and quantization. The different steps in image processing are, image acquisition, enhancement, segmentation, feature...
extraction and pattern recognition. An extension of the application of image processing in the field of medical sciences is called medical image processing. This involves use of image processing techniques to create visual representations of the interior of a body for clinical analysis. The use of medical image processing to assist doctors in diagnosis of diseases is called Computer Aided Diagnosis.

With advancements in the field of image processing and data mining, detection of the abnormalities has been automated to enable early detection and treatment. The CAD system for eye diseases falls under the Supervised Learning techniques. This technique refers to methods that enable creation of a correlation with different features and labelled outcomes. The subset of Supervised Learning techniques are summarized in Figure 1. Few of these include KNN, Naïve Bayes, Adaboost Classifiers, tree-based Classifier, ELM classifier, SVM and LIBSVM classifier etc. The main objective of this paper is to summarize the various CAD techniques adopted for early detection of eye diseases. Different feature selections that have been used and classification techniques for identification of the retinal disorders are discussed.

**Figure 1: Subsets of Supervised Learning.**

**Literature Review**

Most of the research around CAD for eye diseases are based on tree / linear / probability based. The application and the accuracy of the different approaches are discussed below.

**Tree based supervised Learning**

In tree based supervised learning, the dataset is segregated in multiple levels to create homogeneous sets that identifies a target variable. The root of the tree starts with the entire data set and then branches out to create homogeneous groups. A simple representation of the tree based classification is given in Figure 2. Research done based on tree based supervised learning are summarized below.

**Figure 2: Illustration of tree classifier.**

Amin et al[^2] paper deals with automatic classification in exudate and non-exudate region in retinal image. Preprocessing of candidate lesion extraction, feature extraction and classification is done. The Gabor filter is used in grayscale image for lesion enhancement. Segmentation is done based on mathemodial morphology. The feature set selection is done be combing mathematical and geometrical features. KNN and tree based classifier are used for classification.

Koh & et al[^3], uses 2D continuous wavelet transform decomposition on fundus images. Energy features and various entropies are extracted from decomposed images. The adaptive synthetic sampling approach is applied to balance normal and abnormal data sets. Here extracted features are ranked by significance. These features are used to train random forest classifier.

Gupta & et al[^6], discusses modeling of micro patterns of local variations using texture based analysis. Performance of features and patch level NVE prediction performance is analyzed. Patch level grades as Proliferative Diabetic Retinopathy (PDR) present or absent. It uses multi scale AM-FM features and vessel ness map features. Random forest classifier is used to manage high dimensionality due to large size of descriptor. The proposed method indicates good performance for localization of NVE region and identification of PDR.

Fraz[^7], discusses how an automated multiscale segmentation using exudates in which ensemble classifier is applied . The candidate exudates are extracted at fine grain and coarse grain levels using morphological reconstruction and Gaber filter respectively. Region based features are computed from candidate regions to train ensemble classifier for classification of pixel as exudate and non-exudate.

Gargeya & et al[^10], Data driven deep learning novel diagnostic tool. It combines the benefits of adapting artificial intelligence and fundus photography. The
algorithm classifies color fundus images as diabetic retinopathy and healthy using tree based classifier.

**Linear Classification**

Object characteristics are classified through linear combination of feature values. A simple representation of a linear classifier is shown in Figure 3. Significant research contributions in the field of CAD through linear classification were noticed and are summarized below.

![Figure 3: Illustration of linear classifier.](image)

**Guo & al**

proposes a method to exploit fundus image for cataract classification and grading. Two feature extraction methods based on wavelet transformation and discrete transformation are adopted. Once feature extraction is completed, the multiscale discriminant analysis algorithm is used for cataract classification.

**Singh & al**

recommends a wavelet feature extraction followed by optimized generic feature selection combined with various learning algorithms and various parameter settings. DWT features in conjunction with KNN, ANN and SVM classification has been applied for classification.

**Harry Pratt & al**

uses convolutional neural network for diagnosis of diabetic retinopathy. Data augmentation with convolutional neural network architecture is used to identify intricate features like micro aneurysms, exudates and hemorrhages on the retina. Then automatic diagnosis is done without user input. The Kaggle data set was used for this purpose with an accuracy of 75% and sensitivity of 95%.

**Maheshwari & al**

discusses automated diagnosis using digital fundus images based on empirical wavelet transform. EWT is used to decompose images and correntropy features obtained from decomposed EWT component. The features are extracted and ranked using T-Value feature selection algorithm. The classification of glaucoma is done using least square SVM.

**Zhu & al**

adapts a supervised learning method based on extreme learning machine to segment retinal vessels. 39D discriminative feature vectors having local features, morphological vectors, phase congruency, hessian and diverge of vector fields is extracted. As a next step, matrix is constructed for pixels of training set based on feature vector and manual labors. This acts as an input to the ELM classifier. The output is the binary retinal vascular segmentation. Optimization processing is implemented to remove regions less than 30 pixels.

**Albarrak & et al**

discusses a novel approach using 3D image classification. Each image is recursively decomposed till homogenous regions are arrived. A region is represented by histogram oriented gradients that are transformed to set of feature vectors. The Gaussian mixture model is used to generate a dictionary and improved fisher kernel is used to encode feature vectors. Single vector feature for each volume is generated and fed into a classifier.

**Srivastava & et al**

proposed a method to detect microaneurysm and haemorrhages – typically referred to as red lesions. The primary challenges faced include false detection of blood vessels and different sizes of red lesions. Novel filters are applied and classification of lesions are based on elongated vessels compared to circular blob like structures. To address the challenges of different size of red lesions, the Srivastava proposes the application of a proposed filter on patches of different sizes instead of full images. Patches are obtained by dividing original image using a grid whose size determines patch size. Various grid used are combined using multiple kernel learning.

Arunava Chakravarty et.al
discusses a solution to overcome the inaccuracies faced in optic disc and cup segmentation. A variety of features like of texture of projection features to capture shape and textural changes and bag of visual words to capture color information have been identified to enable error proofing and reduction of inaccuracies in the classification process.

**Probabilistic Classification**

Probability distribution of the observations over a set of classes enable identification of the labelled outcomes. Many models that are challenged with predicting based on the underlying physics have been successful with this type of classification. Few examples of the application of the classification are discussed below.

**Aggarwal & et al**

proposes a system comprising of two stages where the first stage involves detection of blood vessels using median filtering followed by morphological operation on retinal images. Here the main blood vessel is detected segmentation of only the main blood vessel is done. Next step involves the localization of the optic disc based on the property that optic disc is the brightest portion on the retina. The histogram matching approach using KL divergence method is used.

**Roy Chowdary & et al**

discusses ways to detect optic disc boundary and location of the vessel origin pixel. Here the optic disc is a combination of bright regions lying in close vicinity of blood vessels. Six characteristic features of bright optic disc are
instrumental in separating bright optic disc region from non-bright optic disc region by using gaussian mixture model. The optic disc and position of vessel origin are very important anatomical features in images obtained from the fundus. The vessel origin is an important factor in detecting maculopathy and macular edema. Optic disc segmentation algorithm shows a success of 99.93% in detection of optic disc boundary and vessel origin with less than 12 pixel error on images.

Wu & et al[1], proposed a method for automatic detection of micro microaneurysm in eye fundus diseases as early and accurate detection of microaneurysm is important in diabetic retinopathy detection. Proposed method consists of 4 main steps. Preprocessing during which illumination and equivalization is done. Followed by candidate extractor during which clahe enhancement and smoothing is done. Feature extraction is then accomplished by extracting local features, peak features and shape intensity features. KNN classifier is used to classify the images as spurious or microaneurycit.

Xu & et al[6], proposes a supervised classification of artery and vein in retinal images using pixel based method. The intra image regularization and inter subject normalization are applied to reduce differences in feature space. First order and Second order texture features are utilized to capture discriminating characteristics.

**Classification accuracy**
The feature extraction procedures and classification algorithms discussed above have been used across different retinal abnormalities. The following table summarizes the accuracy attained as reported by the different authors.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Author</th>
<th>Application</th>
<th>Classifiers and Accuracy</th>
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<tr>
<td>1</td>
<td>Wu, B &amp; et. al.</td>
<td>Diabetic Retinopathy</td>
<td>KNN, Naive Bayes and Adaboost Classifiers – 95.6%</td>
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<td>2</td>
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<td>Diabetic Retinopathy</td>
<td>KNN and tree-based Classifiers – 98.58%</td>
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<td>3</td>
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<td>Diabetic Retinopathy</td>
<td>Random forest classifier – 92.48%</td>
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<td>4</td>
<td>Zhu, C &amp; et. al.</td>
<td>Diabetic Retinopathy</td>
<td>ELM classifier – 96.7%</td>
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<tr>
<td>5</td>
<td>Xu, X &amp; et. al.</td>
<td>Diabetic Retinopathy</td>
<td>KNN classifier – 92.3%</td>
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<tr>
<td>6</td>
<td>Gupta, G &amp; et. al.</td>
<td>Diabetic Retinopathy</td>
<td>Random forest classifier – 97.5%</td>
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<td>7</td>
<td>Fraz, M. M &amp; et. al.</td>
<td>Diabetic Retinopathy</td>
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<td>8</td>
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<td>9</td>
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<td>11</td>
<td>Guo, L. &amp; et.al.</td>
<td>Cataract</td>
<td>Multi-Fisher Classifier – 90.9%</td>
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<td>12</td>
<td>Singh, A &amp; et. al.</td>
<td>Glaucoma</td>
<td>KNN (89.48%), ANN (94.75%) &amp; SVM (84.21%) Classifier</td>
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<td>13</td>
<td>Maheshwari, S &amp;et.al.</td>
<td>Glaucoma</td>
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<td>14</td>
<td>Chakravarty, A., &amp; et al.</td>
<td>Glaucoma</td>
<td>SVM Classifier – 73.28%</td>
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<td>15</td>
<td>Roy Chowdhury, S &amp; et. al.</td>
<td>Diabetic Retinopathy/Glaucoma/ AMD</td>
<td>Gaussian Mixture Model (GMM) classifier – 98.8%</td>
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<td>16</td>
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<td>17</td>
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<td>SVM – 76.77%</td>
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<td>18</td>
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<td>Diabetic Retinopathy</td>
<td>SVM - 75%</td>
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**OBSERVATIONS**
It has been observed from the following research papers that lots of methods using different features and classifiers have been used in automated diagnosis of retinal diseases and with the training sets and testing sets from databases like ORIGA, DIARETDB1, DRIVE, STARE the researchers have been able to obtain a detection accuracy of around 98% for a limited set of data.

**CONCLUSION**
In the last decade significant amount of research had gone through in detection of eye related diseases using computational methods. Many of the methods attempted includes classification by classifiers like SVM, Random
Forest, Gaussian method etc in conjunction with different feature selection methods. These methods have reached an entitlement in terms of detection accuracy. The next level of improvement can be attempted through methods like convolutional neural network.

**REFERENCE**


