Synopsis on
Development of Automated Detection Technique for Diabetic Retinopathy

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List of Abbreviations

DR	Diabetic Retinopathy
EM	Expectation Maximization
FHIR	Fast Healthcare Interoperability Resources
HL7	Health Level 7
IoT	Internet of Things
NGO	Non-Governmental Organization
ROI	Region of Interest
SOM	Self Organizing Map
TOI	Times of India
WHO	World Health Organization

1. Introduction

There are multiple ways in which a health facility may be designed and defined like in or outpatient facility, out-reach facility etc. In all cases the primary goal is to bring the health services close to the masses. The world leading organisation World Health Organisation (WHO) emphasises that remote health service are where distance is critical factor in providing access to health care for rural and remote communities [1]. But, with the advent of new technologies such as sensors and cloud now people in urban areas can also avail medical services at home. So, there are many forms of services viz. Community Service, Telemedicine or pharmacy, Tele healthcare or remote consulting services and remote monitoring [2, 3, 4]. All these forms of services intend to improve the access of health to people and in many cases provide the unimaginable facilities for people who are suffering from blindness related issues [5]. Almost all kind of medical devices can be connected using microcontroller and wireless modules. Lot of work is now focused on the integration of the medical devices and sensors due to birth of new health care models [6].

Many developed countries have volunteer eye and other kind doctors who spend weeks of their annual vacation performing these operations just for housing and food, so as to create the possibility of a greater throughput than just one doctor can and is usually organized through some trustworthy Non-Governmental Organization (NGO) [7]. But, in case of India, the situation is different. There are few takers for the job for remote areas [8, 9]. Then, the sheer size of India population (1.3 billion) and land size (3.287 million km^2) forces us to rethink how the delivery of the health services can do. The inevitable growth in technology also intrigues many researchers and entrepreneurs to develop next generations of medical technology [10].

The initiatives in this context show that epidemiological data collection can lead discovery of new vectors of disease and drugs. But such development is not without challenges. Then, evidences from contemporary literature and associated material shows that old, disable and under privileged may find difficult to adopt such services. It all boils down to logistics, funds, and materials and on the people who can operate such services.

According to one of the recent reports in Times of India (TOI), India has largest number (> 15 million) of blind people and there is an acute shortage of optometrist in India at the same time. It is estimated that 75% of these cases are avoidable and the

problems remain a burning issue due to lack of eye donors, eye banks and eye diseases assessment centres [11]. India has about 12,000 ophthalmologists who do not have time and proper facilities to address the flood of people who require eye surgery or corneal transfer [12]. According to article titled 'Silent thief of sight – Glaucoma on rise' there is a large section of people suffering from glaucoma in India [13]. Glaucoma (is collective name of group of eye conditions as a result of optic disc damage) is said to be the third leading cause of blindness in India. It is clear that for the diagnosis there is a need for more sophisticated and more expensive equipment. Then these treatments need lifelong eye drops usage (expensive for those very poor). Also there is always a need to consult the eye doctors. Hence, the urgent need to develop health services in this context. India is also known as 'diabetes capital' of the world as it is predicted to hit 69.9 million by 2025. But, India does not have pan-India level technology or polity to handle such scale of problem. The problem of diabetes leads to complications of eyes called diabetic retinopathy (DR) [13].

The symptoms of the DR remain hidden and it is in the advanced stages that the signs of this medical condition show up [14, 15]. The symptoms of retinopathy include blurred vision and floaters. In this disease, the blood vessels of the eyes are affected, due to which the vision of the person gets impaired. Consequently, the person becomes less mobile and dependant on others for his daily tasks and the situation becomes more pronounced when the person is living in a remote area and needs medical care in this context. This situation can be overcome by using the latest amalgamation of multiple technologies.

There is an urgent need to upgrade, innovate the various ways to handle diabetics, blindness and eye ailments in India due severity of the problems [16]. The solution lies in implementation of systems that are amalgamation of multiple technologies such as medical sensors, image processing and machine learning algorithms [6]. The amalgamation of these technologies can lead to development of common platforms to diagnose multiple eye ailments such as glaucoma and diabetic retinopathy. Similar set of systems/algorithms can find hints in eyes to find diseases for most common types of the eye ailments. As these algorithms would extract information on the condition of blood vessels (vein and artery), optic disc and other parts of the eye [17, 18, 19]. The information can be formalized for detecting multiple conditions. Confocal scanning and fundus photography can help to detect different stages of diabetic retinopathy. Not only these, other complications related to eye also are assessed.

Fundus Photography is a branch of photography that focuses on the images of eyes and is helpful in detecting eye diseases [20]. This branch of photography can help ophthalmic telemedicine become more powerful [21]. These cameras help to document the retina, the tissues in the eye and the neuro-sensory veins and capillaries in the eye. It is performed with the help of many light coloured filters such as red, blue or special coloured dyes (fluorescein, indocyanine green) [22, 23]. In the real sense, these devices are a kind of digital microscope that has attached digital camera having some prefigured filters to maximize the capturing of eye retina. These digital microscopes are extremely helpful in the diabetic screening process and now with the advent of many wireless technologies, these microscopes can now be remotely controlled using Internet based protocols. Figure 1 gives an example of Fundus Photography.

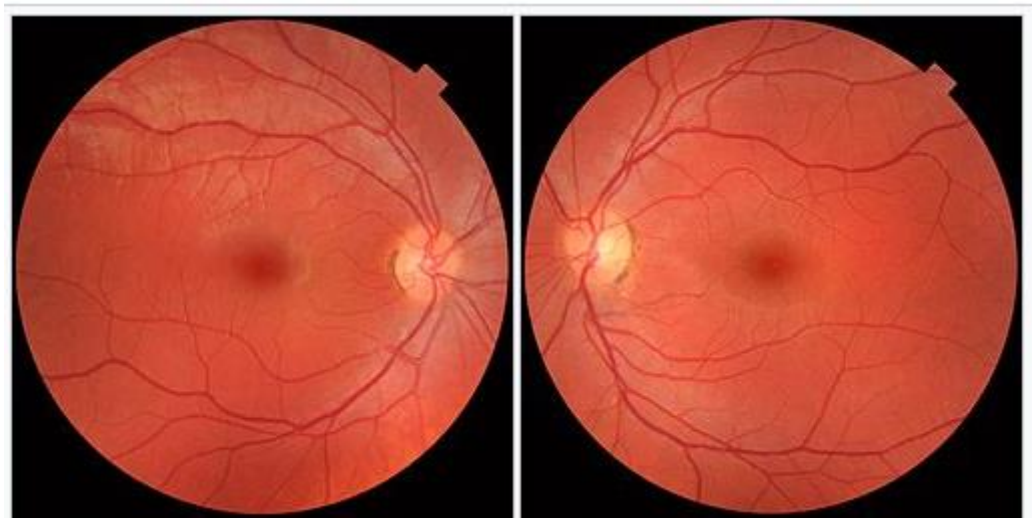

Figure 1: Fundus Photography Images examples [24]

1.1 Confocal Scanning Laser Ophthalmoscopy:

It is another method to capture images of the eyes for identification of the DR and glaucoma medical condition. In fact, in this technology the microscope produces image of high resolution and good quality. It is has been amalgamated with the optical technology to better level of imagery [25]. It scans the eyes in both the directions i.e. horizontal as well as vertically using mirrors. The result is that it is able to stitch the images from different angles into a single medical grade image. The images acquired can be subjected to the image processing function to enhance the optic nerve boundaries. The optic nerves can be further analyzed for their damage.

Technically, however, it should be noted that with all these advancements the images might suffer from the problems of the noise, contamination due to artifacts in the images [24]. At the same time, another observation from different clinical studies shows the quality of images good enough. The technology is easy to implement and handle as it is coupled with the image analysis that are aided with computer algorithms. These days tremendous energy is been diverted to integrate this technology to the detect eye ailments so that the clinical workflows can be optimized for better facilitation of the patients. Figure 2 shows the fundus camera integrated with smart phone to take images of eye retina.

Figure 2: Fundus Camera integrated with Smart Phone [24]

Figure 3 shows the basic scheme of camera, devices and role of doctors in the eye care system. The input and output of the camera are controlled from the smartphone and at the same time the mobile phone services are connected to the eye health care [26].

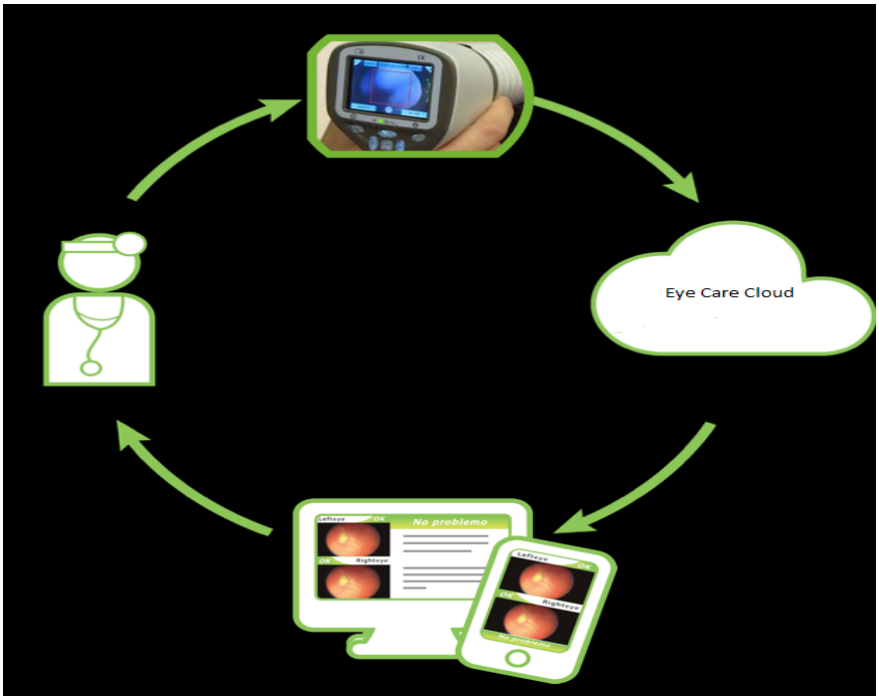

Figure 3: Portable Device Centric Eye Care Workflow [26]

1.2 Eye Care Workflow and Standards of Reporting:

In the context of remote eye care management systems, medical industry standards such as Health Level 7 (HL7) and Fast Healthcare Interoperability Resources (FHIR) are important [27]. These standards provide the various workflows of the work and the standard methods of acquiring, storing and exchanging data between the shared data models. Figure 4 gives a typical workflow case in the context of using fundus photography and computerized record keeping managing eye care centre.

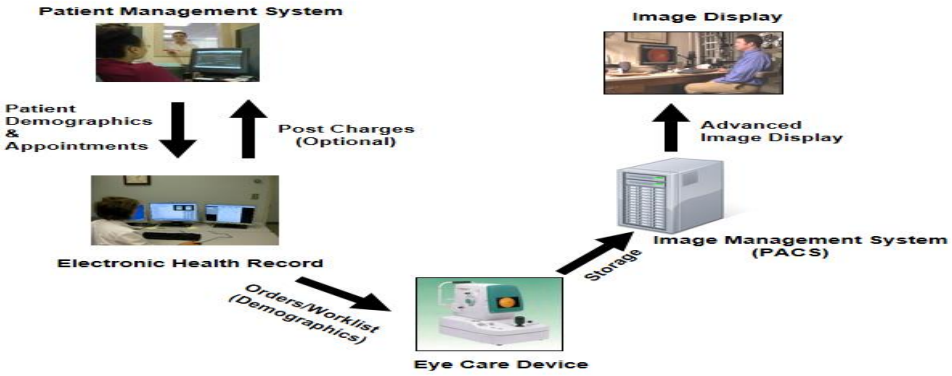

Figure 4: Eye Care Workflow [27]

1.3 Diabetic Retinopathy:

The development of diabetic retinopathy condition is triggered by the diabetic condition - a condition that affects the health of the eye by damaging tissues, blood vessels and blood arteries or by changing the properties of eye tissues. Figure 5 shows eye with DR and normal eye [28]. Figure 6 shows how the difference between a healthy eye and unhealthy eye suffering from diabetic retinopathy. Figure 6 clearly shows that blood vessels weaken and change their morphology and texture. In addition to this, the eye may suffer from unwanted growth of exudates /cotton wool spots that blur the vision and repose to light.

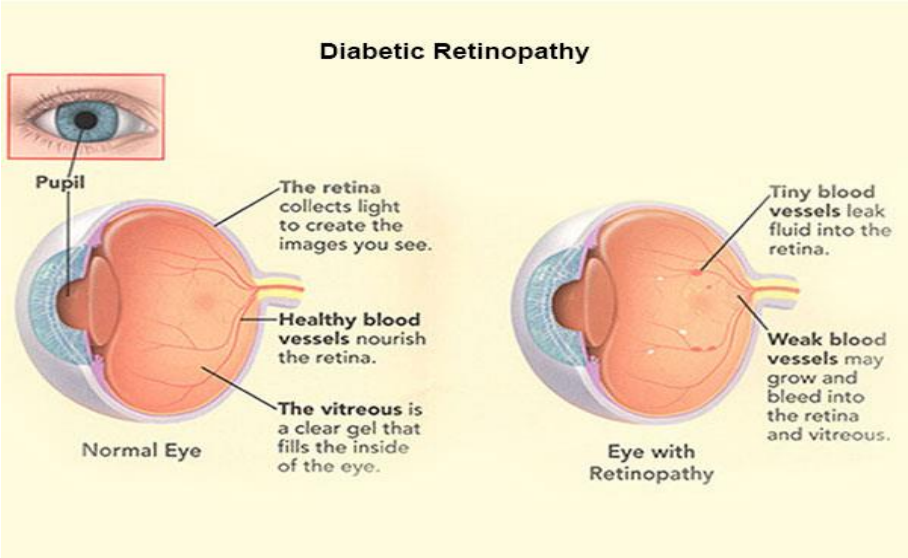

Figure 5: Diabetic Retinopathy [28]

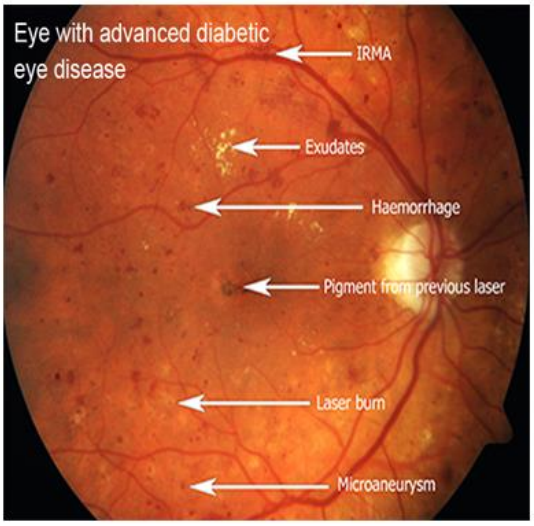

Figure 6 (a): Unhealthy eye

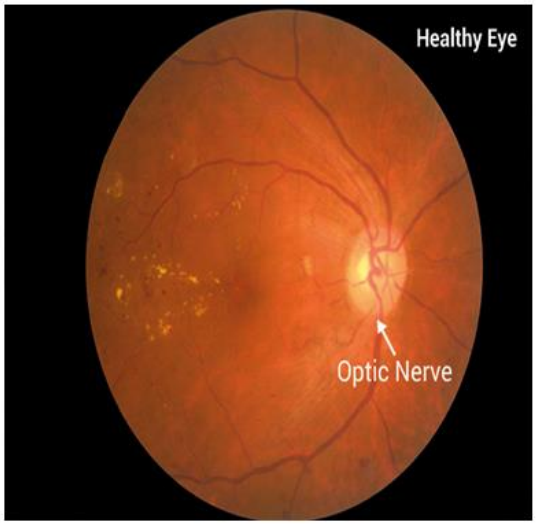

Figure 6 (b): Healthy eye

Figure 6 are sampling images shows the healthy and not so healthy conditions in the eyes. These conditions can be captured and processed for making a fully automatic system of detection with help of image processing methods such as image filtering, image segmentation and image feature extraction. The image segmentation algorithms such as global thresholding, K-means superpixel etc. may be used to get the segment the pixels that makes Region of Interest (ROI). After the accurate segmentation, image feature extraction process is required to be applied.

1.4 Computer Algorithms for detection:

The detection and identification of DR medical condition can be done using four types of approaches if the image of the eyes is processed as a mathematical matrix. The image matrix will provide features that would reflect the medical conditions. These four approaches include:

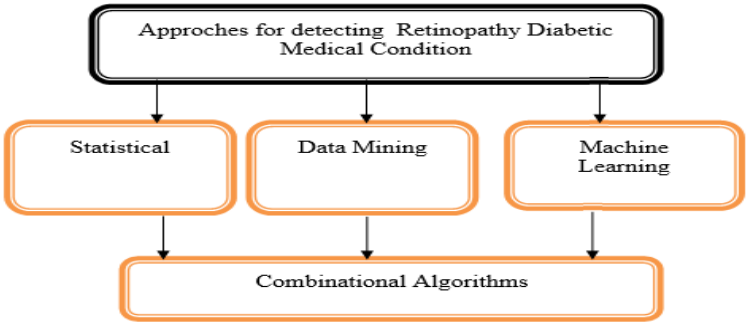

Figure 7: Approaches in the detection

1) **Statistical Mathematics**: In this approach, statistical modelings with the help of regression techniques are typically done. These algorithms construct a trend line based on some feature that can map the optic nerve condition as normal or defective. The features such as the area of the optic disc, neuro-retinal rim area may be used to build a trend line [29]. If there is a deviation from the normal range of area or there are large number outliers in the regression model then we can infer that there is some issue related to an eye ailment. The eye aliment may be related to DR or to glaucoma.
2) **Data Mining**: This is the branch of data science which helps to find insights, patterns, meaning full clusters or groups of data points. In many cases, the researchers have used data mining algorithms to build analytical frequency or cross tables of the diseases related to eyes [30]. They have used algorithms to the group and map the progression of the eye ailment with highly relevant feature information from fundus images. The algorithms include Self Organising Map

(SOM), Expectation Maximization (EM), clustering etc. This approach is normally employed when the image dataset does not have labeled meta-information or simply when the eye images are not marked by the expert. These methods are also referred as unsupervised learning models because no expert person was available to mark/label/group the data or simply it is a case of having a large volume of data and the human experts cannot do the marking in a limited period of time. Grading of fundus images is one of the problems that it faced by current researchers. To solve this problem, researchers are taking help of data mining as well as machine learning [31].

3) **Data Machine Learning Modelling**: This type of mathematical modeling is done when the dataset has rows that are properly labeled or marked. When an expert or doctor identify the medical condition such as bilateral cataract, retinopathy diabetic etc., in the eye image and marks it as per the modality, it is called supervised manual labelling [32]. Such images can be now subjected to supervised learning algorithms. In contemporary literature supervised method is used for detecting eye medical condition which includes decision trees, support vector machine, artificial intelligence algorithms and probability algorithms such as Naïve Bayes. The main requirement of these algorithms is a good size of the dataset if the dataset size is not enough it does not make sense to implement these methods and this is true in case we are using deep learning algorithms [33, 41, 46, 51].
4) **Combinational Approach:** In many cases, a particular approach does not suffice the expected outcome or goal of the study. A combination or sequence of algorithms is required to process in order to achieve goals. Secondly, it must be noted that statistical mathematics is pre-requisite to data mining as well as to the machine learning algorithm. Therefore, the combination of statistical learning algorithms and data mining or machine learning modeling is routine in tasks of data science problems. In the context of the problem undertaken, a combinational approach may work well also.

2. Motivation of Research

Diabetic Retinopathy is one of the leading reason for the loss of sight in developed countries such as the United States. India is already on the way to become diabetic capital of the world. This is quite alarming and this challenge needs to addressed by researchers, doctors, and governments. The Indian government has taken a lot of steps

to curb this medical epidemic with establishments of a large number of eye clinics across India. It is now time to connect such clinics and eye clinical procedures to get connected. The availability of portable and wireless connected cameras can help to accelerate the process. India has a shortage of eye specialists and associated paramedics of this field, therefore this work is highly relevant in the context of India to work with. Moreover, the methods involved in the detection of diabetic retinopathy requires a lot of training and is time-consuming. It takes about 2-3 working days to get a report on the modalities, which leads to delayed follow-up and treatment. Due to this delay, a person coming from any area is almost blind undergoing an unwanted ordeal.

From this research work, novel approaches and frameworks to overcome the challenges of manpower, delay in clinical procedure and automated eye analysis for detection of eye problems will be created. Highly accurate algorithms based on machine learning and fundus images will enhance the medical field of detecting/identification of diabetic retinopathy.

3. Literature Review

This section list the recent works in the area of detection of diabetic retinopathy. The work here gives information on the different types of algorithms, tools and databases that are in use in the domain of detection of diabetic retinopathy.

Table 1: Literature Review

Year of Publication	Author(s)	Title	Source	Summary
2020	S. Mirza, et. al.	Effective Prediction of Type II Diabetes Mellitus Using Data Mining Classifiers and SMOTE	Springer	Clinical record of 734 patients, Used SMOTE, MLP, Decision Tree, SVM Accuracy 94.70%
2020	P. Porwal et. al.	IDRiD: Diabetic Retinopathy – Segmentation and Grading	Medical Image Analysis Journal, Elsevier	Dataset: IDRiD Performed segmentation, grading and localization of

		Challenge		retinal landmarks
2019	Juan J. Gómez-Valverde et al	Automatic glaucoma classification using color fundus images based on convolutional neural networks and transfer learning	Biomedical Optics express	Dataset used 1)Drishti-gs, 2) Esperanza Algorithm CNN The goal of the study comparative analysis of CNN architectures types with best accuracy to detect , glaucoma work validated using objective and subjective assessment
2018	Ahmed Etanboly el at	An Integrated framework for the automatic clinical assessment of diabetic retinopathy grade using spectral domain OCT images	IEEE Journal	Retina Eye scan images of OCT (Zeiss Cirrus HD-OCT 5000) Two-stage deep fusion classifier based on reflectivity, curvature, and thickness of features of the retina. Receiving Operating Characteristics (ROC) were computed with the claim that they are better than the KNN ,Random Forest and

				K-start classifiers
2018	Ramachandran et al	Automated diabetic retinopathy detection in smartphone-based fundus photography using artificial intelligence	The Royal collage of ophthalmologist	296 patient images of diabetic condition were examined and the eye images were captured using FOP smartphone. The output of the algorithm validated with the help of Artificial Intelligence-based software EyeArt
2018	Sumaiya Pathan et al	The Role of Color and Texture Features in Glaucoma Detection	Research Gate	Textures feature used for the detection of Glaucoma Comparative study of SVM and Neural Network Algorithm
2018	Kemal Adem	Exudate detection for diabetic retinopathy with circular Hough transformation and convolutional neural networks	Expert Systems With Applications ,Elsevier	Exudate Segmentation Using Canny Filter and Hough transformation Used for Segmentation. Fundus Dataset used: DiaretDB0, DiaretDB1 & DrimDB. CNN used as

				Classifier , Results claimed 98 to 99 % accuracy for detection DR
2018	Avula Benzamin and Chandan Chakraborty	Detection of Hard Exudates in Retinal Fundus Images Using Deep Learning	Arxiv Repository	The dataset used in this work isIDRiD (Eye Clinic located in Nanded, Maharashtra, India). Convolution Kernels Of Neural Network (CNN) used for detection.
2018	Khojasteh et al	Exudate detection in fundus images using deeply-learnable features	PubMed	Comparative study of CNN, Pre-Trained Residual Networks and Discriminative Restricted Boltzmann Machines for exudate detection . Outcome of the study , ResNet-50 in combineaiton with Support Vector Machines works best with highes accuracy
2018	Zheng et al	Detection of exudates in fundus photographs with imbalanced	PubMed	Deep Convolution Neural Networks have been used to differentiate normal and abnormal exudate

		learning using conditional generative adversarial network		growth in the eyes Since, the dataset was small ensemble convolutional neural network was adopted and to overcome the problem of imbalance conditional generative adversarial network as used. This way the authors were able to get accuracy as high as 95% Dataset tested on these include DiaReTDB1, HEI-MED and MESSIDOR
2018	Shilpa Joshi et al	A review on exudates detection methods for diabetic retinopathy	Biomedical and Pharmacotherapy journal , Elsevier	Discusses the various approached done by researchers for segmenting exudates, optic disc and detection of DR methods. Review techniques include thresholding, clustering, classification and other mix methods.

2018	Marin D et al	An exudate detection method for diagnosis risk of diabetic macular edema in retinal images using feature-based and supervised classification	PubMed	The authors have created a method called Graphical Abstract Diagnoses , which is based on classification technique for detecting risk of diabetic macular edema
2018	Manish Sharma et al	Modular Neural Network for Detection of Diabetic Retinopathy in Retinal Images	Springer , Conference Proceedings	Modality : DR Dataset used is DIARETDB0. Algorithms used is Modular Feedforward Neural Network (MNN). Accuracy 100% normal , 88 % for abnormal retina condition
2018	Zhao H et al	Supervised Segmentation of Un-Annotated Retinal Fundus Images by Synthesis	PubMed	Synthetic Images used for research work .Created with help of Relativistic GAN algorithm. Purpose of reach reduce semantic gap between the query image and real fundus

				image in context of segmentation of the fundus images .
2018	Syedia Tahseen Fatima Bokhari et al	Fundus Image Segmentation and Feature Extraction for the Detection of Glaucoma: A New Approach	Current Medical Imaging Reviews	The paper has two main objectives : 1) Compute Cup to Disk Ratio. 2) Segment Optic disc. Dataset Size : 200 images Modality : Glaucoma Segmentation Method : Circular Hough Transformation & Active Contour Modelling
2018	Baidaa Al-Bander et al	Dense Fully Convolutional Segmentation of the Optic Disc and Cup in Colour Fundus for Glaucoma Diagnosis	Symmetry Journal	Objective of Work : Segment optic disc & Cup Segmentation Algorithm: Comparative study of CNN and classical segmentation methods. Modality : Glaucoma
2018	Y. Hagiwara	Computer-aided	Science Direct	Review on algorithms

	et al	diagnosis of glaucoma using fundus images: A review		, approaches and strategies on the art and science of diagnosis 1) Elements of algorithms that help in detection glaucoma (Data->Image Segmentation->Feature Extraction->Deep Learning Classifications). 2) Deep learning approaches
2018	Panda R et al	Automated retinal nerve fibre layer defect detection using fundus imaging in glaucoma	PubMed	Key Objective : Detection Fibre layer of Retina for analysis of glaucoma condition. Algorithm : RANSAC data fitting to find width of fibre layer. Results: AUC close to 0.87.
2018	Tamonash Basu et al	Multicolour imaging for retinal nerve fibre layer defect	NCBI PMC library	Comparative study of the MCI Multi-Color imaging scanning on multiple

		in glaucoma		patients.
2018	SK Saha et al	Color fundus image registration techniques and applications for automated analysis of diabetic retinopathy progression: A review	Pub Med	Review of Image Registration frameworks. a) Automated Systems of Registration of Fundus Images b) Longitudinal methods of image registration
2018	Piyasena et al	Development and Validation of a Diabetic Retinopathy Screening Modality Using a Hand-Held Nonmydriatic Digital Retinal Camera by Physician Graders at a Tertiary-Level Medical Clinic: Protocol for a Validation Study	PubMed	Description of protocol for screen DR using Hand Held devices. Objective and Subjective validation show protocol and working with hand held devices is robust
2017	Sameer Kanse and DinkarManik Yadav	Retinal Fundus Image for Glaucoma Detection: A Review and	Journal of Intelligent Systems	Dataset: IPN data set, ZEISS data set DIARETDB1 MESSIDOR . Features such as

		Study		Texture , Descriptive statistics are good features that can be mapped to eye modalities Key Findings : Cup , Disc areas and Blood Vessels is one indicator of Glaucoma, KNN SVM is appropriate for automating the Glaucoma Detection
2016	Toy BC et al	smartphone-based dilated fundus photography and near visual acuity testing as inexpensive screening tools to detect referral warranted diabetic eye disease	PubMed	Key Objective: Find suitability and Validate the smartphone image quality for checking eye ailments. Results : The values of Correlation, AUC/ Kappa statics , Sensitivity and specificity show the smartphone is valid and inexpensive screen tool
2016	Adam MK et al	Quality and Diagnostic Utility of Mydriatic Smartphone Photography:	PubMed JAMA	Dataset : 188 images Objective : Can smartphone produce diagnostic quality images

		The Smartphone Ophthalmoscopy Reliability Trial		Outcome : Evaluation of the images shows that smartphone can be used for the diagnoses of eye ailments
2016	Bastawrous A et al	Clinical Validation of a Smartphone-Based Adapter for Optic Disc Imaging in Kenya	PubMed	Dataset(s) : 2152 + 2920 images captured with smartphone (non clinical) Main Objectives : Objective and Subjective Design, Grading of Camera device/images as per the modality. Result : Insignificant difference between the objective and subjective validation
2015	Ramachandran Rajalakshmi et al	Validation of Smartphone-Based Retinal Photography for Diabetic Retinopathy Screening	PLOS journal	Dataset :301 Subjects , 602 Fundus Images Main Objective : Validation & Grading of Images generated by smartphone fundus photography camera. Outcome : Sensitivity and specificity of the images above the range of 97%

2015	Andrea Russo et al	A Novel Device to Exploit the Smartphone Camera for Fundus Photography	Journal of Ophthalmology	Explanation and description of a device based on the principle of ophthalmoscopy fundi
2014	Christopher J Brady et al	Rapid Grading of Fundus Photographs for Diabetic Retinopathy Using Crowdsourcing	PubMed	Dataset : 230 Images Key Objective: Gradation of the Fundus Images using Crowd Sourcing. Outcome : The values of ROC and AUC gives confidence that crowdsourcing can used for grading of the images

4. Current State of Art

Evidences in the current literature shows that the field of detecting eye ailments is undergoing rapid changes. Image processing algorithms are playing important role in detecting different modalities of eye diseases. It can be observed that the current trend in context of this domain is the use of hand held, smart phones, IoT medical devices that can capture fundus scanning based protocol images. Large section of the researchers is using eye image dataset that are in public domain. It is also noteworthy that labeled, verified and annotated images by specialist for the modality are also available but are limited. The most popular methods in image processing include the use of contrast improvement methods, active counter modeling, Circle Hough, Global thresholding, using Image gradient matrix for detecting the size of optic disc. In the context of detecting abnormality of blood vessels, use of image filters and thresholding methods seems to work well. In case of detecting the exudates and tissue matter that blur the vision due to diabetic conditions clustering methods are popular. It can be

observed that in both the cases of retina diabetic and glaucoma medical conditions, most researchers are using machine learning algorithms to automate the process of detection. Most of them prefer this over statistical methods that are based on the regression etc. Evidences in current literature show that neural networks are most popular methods for constructing detection systems but few have addressed the problem of imbalance class dataset, small dataset and other problems such as degree of overlapping between the classes. Python and R machine learning and image processing libraries are mostly used for construction of such systems. Some researchers have also used Matlab and other statistical tools for testing and validation of the results. The popularity of the tools can be attributed to the fact that python and R are open and community sources.

5. Objectives

1. Conduct an explorative study of literature, algorithms and methods involved in image-based detection of DR.

2. Develop a segmentation and extraction algorithm for supporting detecting algorithms of DR.

3. Develop optimized machine learning models that automate the detection of DR.

4. Compare and validate the results for reproducibility of algorithms on accuracy, recall, precision, f1-score.

6. Methodology

This section gives information on the proposed methodology that will be undertaken for overcoming the challenges. For better understanding of the procedure followed in this research work Figure 8 may be referred. It can be observed from the figure that, the first step in this study besides conducting literature survey of the current development in fundus images of DR is to prepare the dataset that is suitable for running the machine and deep learning modelling.

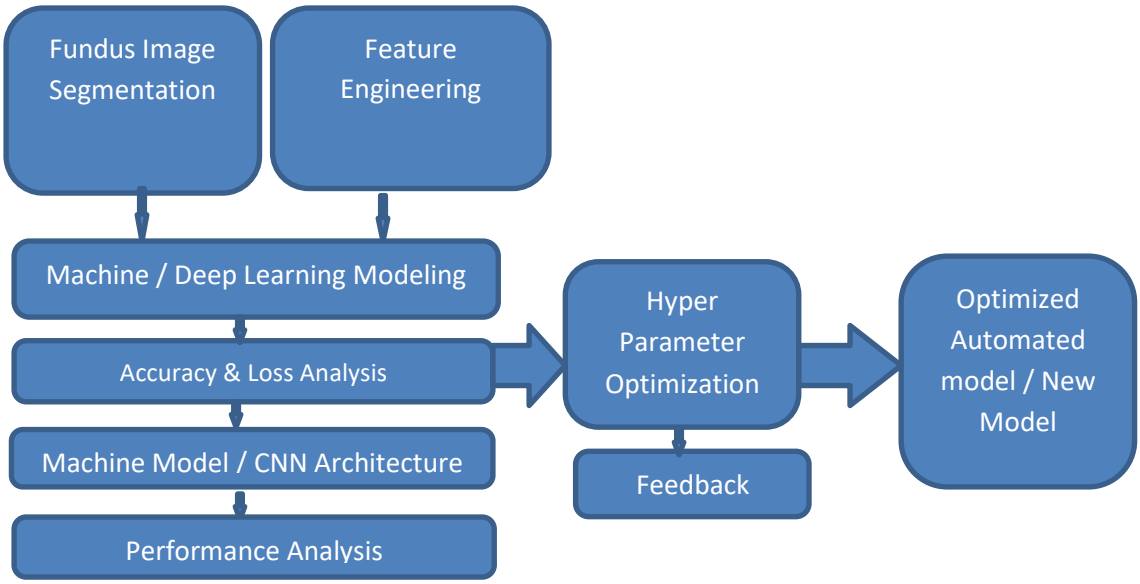

Figure 8: Procedure to be followed

Step 1: In this step, a dataset of fundus images will be analysed and organised in a file server. The images will be evaluated for their quality and other quality parameters. Fundus Image Preprocessing might be required and the following steps might be required:

1) Image Resolution Improvement
2) Image Denoising
3) Image Registration and alignment before classification

Step 2: In this step fundus images will be subjected to multiple segmentation algorithms for the extraction of the blood vessels. Based on the outcome of the multiple segmentation algorithms a new / optimized segmentation algorithm will be developed. This is primarily done because in DR the major impact of the DR is on blood vessels. There is an increase in number of blood vessels and these vessels are sized in terms of thickness and length also changes as compared to the normal healthy blood vessels.

Step 3: In the third step, the labelled segmented dataset will be subjected to the feature engineering process. For feature engineering, the first step is to select appropriate features that can map the DR medical condition from the image. Since, the size, shape, colour of the blood vessels and eye changes due to DR.

Morphological, geometric and features related to intensity of the images will be selected initially. Once this formation of the feature dataset is completed, the dataset will be subjected to the feature selection process. In feature selection method, the dataset will be subjected to multiple statistical methods such as correlation, random forest, importance ranking using statistical test etc.

Step 4: In this step, the selected features will be subjected to the machine selection modelling process and hyper-parameter based fine tuning will be done. Multiple machine learning and deep learning models will be evaluated and based on the feedback a new algorithm will be formulated that works well the DR detection and classification tasks.

Step 5: In this step, the performance evaluation of the models / architectures that have been constructed in the last step will be done. The performance analysis may include metrics such as accuracy, recall, precision and f1-score.

Step 6: Validation of all the models constructed in step 4. The validation methods may include the use of k-Fold strategy with multiple metrics.

7. Expected Outcomes

1) The proposed work will help in building a new space where health care related problems of eyes especially will become more accessible and easy to implement without the need of super-speciality medical practitioners.

2) The work will contribute towards building numerically stable and consistent algorithms and frameworks that can work on different types of images and modalities.

3) The machine learning models will support higher levels of generalizations and optimal accuracy in terms of sensitivity and specificity.

4) This work can lead to the creation of base machine learning models that can become a starting point for building solutions based on transfer learning in the medical imagery field.

5) Such initiatives will support all programs that help to reduce the burden of diabetes and eye problems on society.

6) This research work will help in improving the speed of adoption of Artificial Intelligence in medical science.

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