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Computer-Aided Diagnosis of Diabetic Retinopathy

Tejas Bramhecha, Pranjali Deshmukh

Fourth Year, Bachelor of Engineering, Department of Information Technology, MIT Academy of Engineering, Alandi, Pune, India

Abstract: *The fascinating aspect of our paper i.e. Computer-Aided Diagnosis of Diabetic Retinopathy is to actuate the computer technologies that explains the devastating ideas of technical advancements in biomedical field so that it can be used for an automatic detection of Diabetic Retinopathy (DR). Basically, DR is an eye disease caused either because of damage to the retina or by retinal detachment due to the most common disease called as diabetes mellitus. DR is said to be one of the most critical diseases which can cause severe injuries to human retina which in turn directly results in the blindness. It is one of the besetting infirmities found among the old aged people who have had the diabetes from last ten or more than ten years. According to the case study done in USA, every year DR accounts 12 % of all new cases of blindness. Specifically, while speaking about human eyes, many modern techniques still gets stuck up & are incapable when it comes to cure eyes once it gets damaged thus either or solution for this is to take caution before it gets damaged. This paper explains an analogy & ideas about an early detection & diagnosis of DR. Here we are more focused on designing a software to realize automation technologies whose functions & mechanisms facilitates us a very effective approach to detect whether DR is present or not & if yes which measures could be taken in order to avoid the complications of the case. Till the date very less work has been done in this field, here is henceforth a dire need to look at more provocative & adaptive approaches to make & build up an advanced automation capabilities in the computer systems.*

Keywords: *Diabetic retinopathy, matched filters, fundus Camera, exudates, haemorrhages, micro-aneurysms.*

1. INTRODUCTION

Nowadays, diabetes is more common disease seen amongst people. It is usually caused by low level of insulin present in the human body which results in high blood sugar level over a long time. It may cause many problems like kidney failure, heart-related diseases & may even cause severe damage to the eyes & patient may be followed by many undesirable effects. No doubt that DR is a result of prolonged diabetes. It causes damage to the blood vessels present in the human eyes which may lead to the blindness or vision loss. In a very first phase of DR, the patient starts losing his sharp vision & then over a course of time, the patient becomes completely blind. Experts have given mainly two possibilities for the vision loss due to DR & that are as follows:

1) High sugar level causes fluid in the lens to get accumulated inside the eyes leading to clotting & blurred vision. Then due to blurred vision, the lens starts to swell & the result is blindness.

2) Development of fragile blood vessels leads to the leakage of blood inside retina that later on beclouds the vision of eyes.

Fig 1:*Fundus Image of DR*

To analyze the changes occurred in a retina, eyes are needed to be scanned from inside which provides us the detailed structure of blood vessels & pathological changes. A fundus camera is used for capturing the images of interior parts of the retina with the help of low power microscope having camera attached to it. As it is essential to find whether patient have any eye disease or not, it is mandatory to examine the fundus image & it is the most crucial procedure in ophthalmology. Here on further, we have explained various steps of computer-aided diagnosis using which software will automatically generate a report after detecting the disease & so we can diagnose it as early as possible.

Our system can play a paramount role in collecting the detailed information related to an eye of a diabetic person. The system has the functionality to check the visibility index before proceeding to the examination of eyes. The scope is limited in terms of size of fundus image & after detection of DR affected person; the information is congregated and reserved in separate storage space provided by the system. The database of the patient is handled, managed by the authorized MM-Db manager. The consistency & integrity of data must be maintained. The stored data can be used for further analysis of changes occurring in the retina of patient's eyes and data can be modified as and when required to track the damages occurred due to DR. The system generated report will be helpful for the ophthalmologists in claiming the damage of retina.

2. DIABETIC RETINOPATHY

As stated above, the basic reason of DR is diabetes & DR end up with temporary or permanent visual impairment. According to the survey of *International Agency of prevention of blindness*, across the globe, there were 366 million people having diabetes in 2011. Moreover, the most threatening prediction given by this foundation was by 2030 there will be 552 million people living with diabetes. The statistics given by *World Health Organization* in 2005 states that more than 75% of people who have diabetes for more than 20 years will surely have some form of DR. So this problem is not only limited to specific countries like US or India but it has become the most serious issue of the whole world to think on. *The Fred Hollows Foundation* and *Helen Keller International* organized a meeting in Bangkok to bring NGOs together to straighten out the problem of DR and to contribute their efforts.

Predictive pedagogy has shown the relevant forecasting of probable impacts of DR. On the iterative side that can humiliate the sense of an increase in frequency of retinal disorder & it's needed cure. This can fill the gap among proficient practitioners to identify the impacts in vital sense of cure of diabetic retinopathy. CAD technologies help in enhancing the ability to accurately diagnose & recognize diseases & thereby help in taking curative measures for it & so we can reduce illumination frequency of retinal disorder by cumulative analysis, prediction & frequently predictive survey.

A) Explanation:

Before diagnosing any disease, we need to understand its root cause. So, there are mainly 3 stages of DR that are given as follows:

1) Background diabetic Retinopathy (BDR): This is the first stage of DR wherein it causes mild damage to the human retina. Blood vessels & arteries of the retina become weak & haemorrhage starts which after leads to swelling of retinal vessels. Vision is decreased in the first stage & BDR progresses quickly.

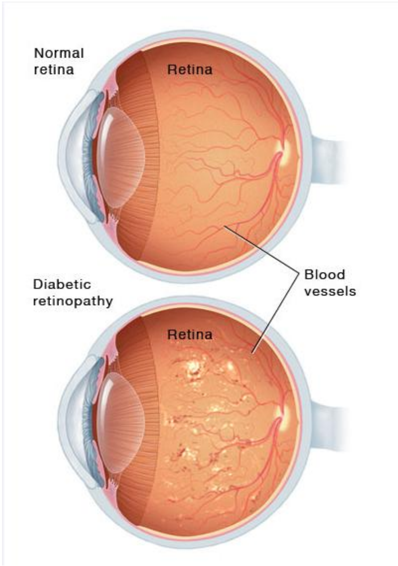


Fig 2: *Normal retina vs. DR affected retina*

2) Proliferative diabetic retinopathy (PDR): This is the second stage of DR. Fragile blood vessels start to develop & it is because of the oxygen circulation problem in the disease affected areas of the retina. Human body always attempts to maintain the proper circulation of oxygen in the body & hence when vessels become oxygen deprived, body system creates new vessels in the retina. This is an unfavorable condition that causes blood to leak in retina causing spots in the eyes.

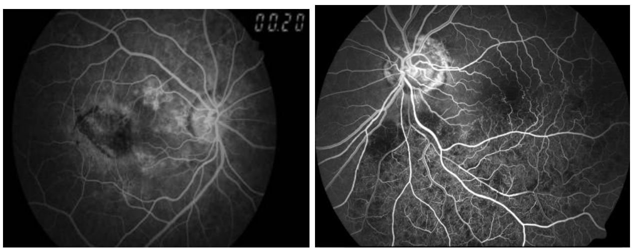


Fig 3: *Images of PDR*

3) Severe diabetic retinopathy (SDR): This is the last stage of DR. The result of this stage is retinal detachment which finally turns out in blindness. Progression of retinopathy is associated with the severity and length of time that *hyperglycaemia* exists. If diabetes is diagnosed before the age of 30, the incidence of DR after 10 years is 50%, rising to 90%

after 30 years more [16]. Randomized trials have clearly shown that the risk of developing severe visual loss from Proliferative DR can be significantly reduced through the use of a *laser photocoagulation*. It uses heat from laser to destroy abnormal/leaking blood vessels in retina. In *focal photocoagulation*, only specific blood vessels are sealed wherein *scatter photocoagulation* slows down the growth of abnormal blood vessels. Regular dilated eye examinations are effective approach in detecting & treating vision-threatening DR. Guidelines for frequency of dilated eye examinations have been largely based on severity of DR. For severe DR, frequent eye examinations are needed to examine & determine when to initiate the treatment & for patients with less damage to retina, need of examinations is less clear.

3. COMPUTER- AIDED DIAGNOSIS

Automated diabetic retinopathy thus detects the various types of lesions of the retina that are exudates, microaneursyms & haemorrhages & then later on, assessment of severity of DR is done. Description of above terms is as follows:

1) Exudates: The bright and reflective area seen in the eye is nothing but the exudates which represents the accumulation of protein and lipids in it. If these lesions are seen near macula then it results in an impaired vision.

2) Haemorrhages: As explained above, in the second stage of DR, retinal vessels become ischemic i.e. oxygen deprived so it damages retinal vessels and become leaky. Henceforth the area of resulting leakage is defined as haemorrhages.

3) Microaneurysms: Microaneurysms are swelling of blood vessels near the eye. The detection of microaneurysm is very important in recognition of DR.

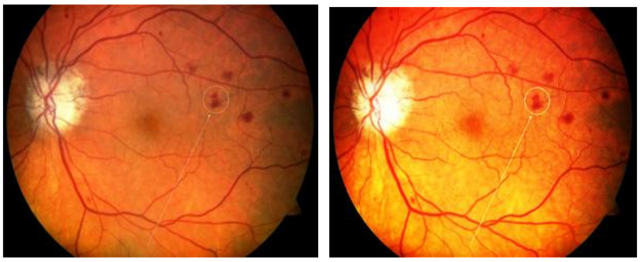
Till the date, several computerized methods based on digital image processing were proposed. We may use screening methodology in which at the very first stage digital recording of fundus images is done & later using neural algorithms it analyzes the DR. The benefit of screening method is its cost-effectiveness. The screening technology provides more efficient & flexible way to analyze the DR. The performance of the screening method in terms of detecting exudates is about 88.5 % & in detecting haemorrhages & microaneurysms is about 88.7%. According to the paper published in *British Journal of ophthalmology*, if we use a neural network as a screening tool then detection rate of recognition of exudates & haemorrhages is 93.1% & 73.8% respectively. The prospect behind medical image analysis is to develop computational tools that will assist both qualification & visualization of interesting pathology & anatomical structures. Image processing can reduce the workload on screeners & play a central role in quality assurance tasks as well.

A) Screening Technique:

The steps to find important features of DR are as follows:

1) Digital recording of fundus image: Fundus images are now taken at almost every ophthalmology center. These are taken in order to view the interior part of an eye & to study the risk factors if present. It gives clear images of blood vessels in the retina. (Dilation of the pupil must be done before taking the fundus images.)

2) Pre-processing of image: It is done in order to improve the quality of the image. It is also called as Color contrast enhancement. It is the most common practice in image processing. It is also useful to improve details in photographs that are over or under-exposed & in fact it reduces the artefacts present in the fundus image. The effect of color contrast enhancement is as shown below & one can easily visualize the changes made.



[A] [B]

Fig 4: *[A] Normal image [B] After providing contrast effect.*

3) Recognition of main retinal elements: The most important retinal components are optic disc & Fovea. The third step of screening method is to identify them manually in the fundus image. Fovea is the region where center field of vision is focused & retinal cones are concentrated here. The Optic disc is the point of exit where axon cells leave the eye. It is identified by the area of highest variation in the intensity & fovea is identified by the darkest black spot in an image showing that vision is focused there.

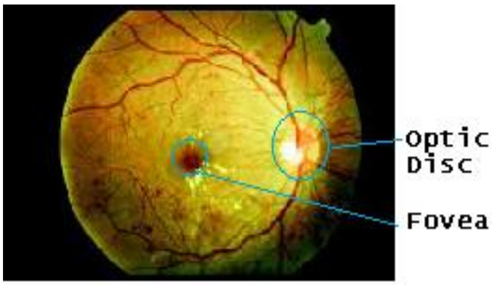


Fig 5: *Recognition of main retinal elements*

4) Exudates detection: To detect if any exudates are present we need to apply *recursive region growing segmentation* algorithm (RRGS). First of all, we have to convert the fundus image into grey scale format. Medical field requires images to be converted into grey scale images to reduce the difficulty in visualization. In image processing techniques it is hard to interpret the colored images & for more simplification grey scale images are useful. It also increases the speed of the system as grey scale images usually take less time for processing as compared to colored images. If you are going to write any code for image processing then the length of the code is reduced as well. Identifying & locating optic disc area has become pre-requisite for the detection of exudates as optic disc in human retina is kind of similar to exudates in terms of shape, color & contrast. So the recursive region growing algorithm may also detect & highlight optic disc area considering it as an exudate. The Optic disc is having the highest intensity in the fundus image so to detect optic disc RRGS algorithm is been used.

Step-I: RRGS algorithm used to detect the optic disc: Seed point of highest intensity is selected & then using 8 point connected method it checks the pixels in its proximity. Then it adds them to the set of pixels if its intensity is similar to the seed point & the method is continued until it finds the area of same intensity. This method has one trap in it. As optic disc is the entrance region of the blood vessels, so no doubt there can be interference of the blood vessels which may result into partial detection of optic disc. To avoid this problem we can use *connected component analysis*. If any other component exists, whose centroid is at 25 pixels from the centroid of largest component of optic disc which we have already found using RRGS, then that component is merged with the larger one and a new centroid is found. This centroid is assumed to be the centre of the optic disc & the set of pixels coming under the area of optic disc are recorded. Now to detect exudates again RRGS algorithm is used but this time set optic disc area which we have found in step-I are excluded & we highlight only those pixels that are found in step-II.

Step-II: RRGS algorithm used to detect exudates: It is a pixel based algorithm. RRGS take up any seed pixel from pre-processed fundus image & initializes the algorithm. It uses four-point connected method which is mainly used in computer graphics. Let us take any point as p(x, y) & as shown in below figure Fig.6, p has neighboring 4 pixels having coordinates (x+1, y), (x-1, y), (x, y+1), (x, y-1). Then intensity difference is found out after comparing p & p_i & if the difference found out more than or equal to threshold values say as 10 then p_i is then added to set of p & p_i is set as p. The cycle is iteratively repeated until the whole image is segmented. The intensity of segmented region which was found to be greater than a threshold value is set to white intensity. Finally, these exudates recognized regions are overlaid on original image & exudates are detected & highlighted.

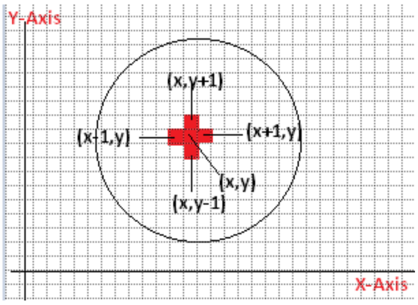
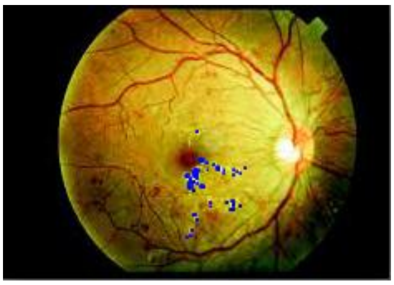


Fig 6: *RRGS*

[A]

[B]



[C]

Fig 7: *[A] Original Image [B] Recursive region growing algorithm [C] Result of exudates recognition.*

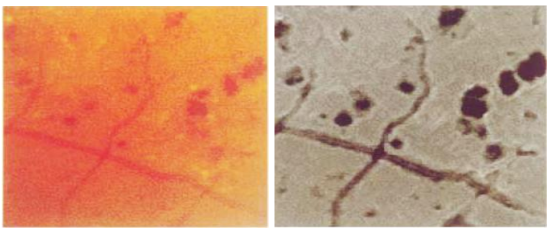
5) Haemorrhages & microaneurysms (HMA) detection: This is the last step to detect whether DR is present or not. Here we detect Microaneurysms and haemorrhages if present.

Step-I: The foremost step to detect DR is to apply 'Moat Operator' on original fundus image. It is used to optimize recognition of HMA. In order to sharpen the edges of red lesions against the red-orange background, moat operator is used.

B) Working of moat operator:

Step-I: In moat operator, we used two main concepts i.e. one from a mathematical background (Fourier Transform) & other is from electronics background (High-Pass Filtering). We need Fourier transform because in the retinal image the blood edges & damages contribute to high- frequency components & we need to identify those components. So, what we do here is to convert the spatial domain of image to frequency domain. Let us take f(x, y) in spatial domain which is converted to its Fourier transform f (u, v) in frequency domain. Once we converted the image into frequency domain, it is given to high pass filtering process which attenuates the low-frequency components without disturbing high-frequency components & image sharpening is done. Later on by using inverse Fourier transform we again convert the frequency domain into its original spatial domain.

Step-II: Recursive Region Growing Segmentation algorithm is applied.



[A] [B]

Fig 8: *[A] Part of original image [B] Moat Operator applied [5]*

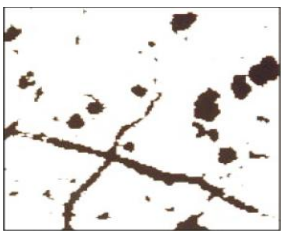


Fig 8: *[C] Image after application of RRGS algorithm [5].*

Step-III: As HMA & blood vessels both are red in color there will be ambiguity for the system when it comes to differentiate between blood vessels & HMA & hence to avoid this confusion we need to separate out the blood vessels & HMA using the neural network. Perceptron multilayer neural network can be used here. A multilayer perceptron (MLP) is a feed-forward artificial neural network model that maps sets of input data onto a set of appropriate outputs [17]. The feed-forward neural network was the first and simplest type of artificial neural network devised. In this network, the information moves in only one direction, forward, from the input nodes, through the hidden nodes (if any) and to the output nodes. There are no cycles or loops in the network [18].

[D] [E]

Fig 9: *[D] & [E] Separation of vessel & non-vessel area using neural network [5].*

Step-IV: Detected haemorrhages & microaneurysms are overlaid on original image.

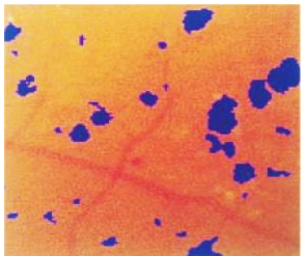


Fig 9: *[F] HMA are overlaid & highlighted [5].*

Henceforth herein we can detect important features of DR. Later on using programming constructs in software based on the output of the system we can decide whether DR is present or not & if present, which is the stage of disease & what measures are needed to be taken. (Note: - Although Computer-aided technologies provide 85 to 87% of sensitivity, one must consult an ophthalmologist after detection of PDR or SDR & it is supposed to take follow up unless & until some curative measures are taken.)

4. ADVANTAGES

Screening technology plays a vital role in automation of computer systems which can be used to detect DR. The advantages of screening methodology are given as follows:

1) The advantage of this system is that you don't need a trained personnel or specialists to screen a retinal image. Hence it saves the cost of the system.

2) Secondly, there is no necessity to go through rigorous amount of tests & wait for results rather than people can use this technology & can save their time.

3) It significantly reduces the burden on ophthalmologists.

4) Primary care centers can also provide this automation technique so that people don't have to seek appointment of ophthalmologists.

5) It provides ease of use and associated patient comfort.

6) The detected microaneurysms & exudates are then validated by comparing it with ophthalmologist's hand drawn ground truth.

5. COMPUTER-AIDED DIAGNOSIS (CAD) IN BRIEF

Computer-Aided Diagnosis has played an eminent role in the medical field. Now IT trends have not been only limited to specific fields but there is exaggerative need to implement available technologies in every possible area. The new technologies are evolving day by day & do make an impact on social life of every person. The last century has witnessed the vast development of IT technologies. While speaking specifically about medical field the technologies like Magnetic Image Resourcing (MRI), Ultra-sonography had left a foremost impression on people & had assisted the medical fraternity immensely. All CAD techniques have undoubtedly benefitted doctors in giving more accurate & timely diagnosis of diseases so as to improve patient care. As stated in a paper of *image retrieval for CAD*, the CAD technologies help in enhancing the ability to accurately diagnose & recognize diseases & thereby help in taking curative measures for it.

CAD systems seek to highlight suspicious structures. Today's CAD systems cannot detect 100% of pathological changes. But the hit rate (sensitivity) can be up to 90% depending on system and application. A correct hit is termed a True Positive (TP), while the incorrect marking of healthy sections constitutes a False Positive (FP) [23]. CAD systems aim to provide computer output as the second opinion in order to assist physicians/ ophthalmologists/ radiologists etc. in image interpretation & detection of abnormalities, qualifications of disease progress & alternate diagnosis. The mentioned screening technology is one of the application of CAD. CAD is currently being used for detection of breast cancer & lung nodules also. However, invention of CAD technologies has been the area of interest in recent past. So to approach this kind of automation, CAD techniques need to be addressed & integrated into computer assisted diagnostic environment. To support clinical treatment, it requires intelligent systems that have the capability to recognize & understand the complex content of medical images. CAD technologies truly revolutionized the diagnosis of many diseases.

6. CONCLUSION

The prevalence of diabetes is increasing day by day & because of high sugar level in the body over a long period causes vision loss & hence the final goal of this paperwork is to focus on the computer aided technologies that can be used for the automatic detection of DR and its early diagnosis. Earlier it was a tedious and time-consuming process to decipher the changes occurred in the retina due to DR. The Computer-aided diagnosis can significantly reduce the burden on ophthalmologists and alleviate the problem of the inter and intra-observer variability.

It's totally impractical to detect diabetic retinopathy by simply looking at the retinal image so it is crucial to identify lesions present in retina automatically. The Computer-Aided Technologies stated in this paper has nearly better performance in diagnosis, in fact, experts do advise us to go for these kind of advanced methodologies. Recently many researchers have opted this subject as their area of their interest. Since there may be traps & bugs present in every system built by human & we agree upon the fact that no system gives 100% of efficiency but we also think that this can be treated as secondary opinion over the ophthalmologists'. We strongly believe that if we could take more provocative steps towards these advanced technologies, it will surely help us to avoid or reduce the possibilities of vision loss or so called as blindness.

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