

Review of Image Processing Methods on Diabetic Related Images

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Abstract:

As Diabetes Mellitus combined with other ailments will become a deadly combination, hence there is an urgent need to break the link between diabetes and its related complications. For this purpose image processing based analysis can potentially be helpful for earlier detection, education and treatment. Medical image analysis of Diabetic patients with its related complications such as DR, CVD & Diabetic Myonecrosis (i.e. on Retinal Images, Coronary angiographs, Electron micrographs, MRI etc) is to be the aprioristic because of its more prevalence. Thus the main work of this paper is on literature review about Diabetes and Imaging such as the Prevalence, Classification, Causes and Medical Imaging & Survey of Image processing methods applied on Diabetic Related Causes.

Keywords — Image, segmentation, retinopathy, Myonecrosis,

1. INTRODUCTION

Diabetes is the biggest health challenge of the 21st century. Diabetes is a chronic condition characterized by raised blood glucose levels. It develops when the pancreas does not produce enough insulin or when the body cannot effectively use the insulin it produces. It is the major cause of blindness, obesity, ageing population, heart disease, stroke, amputations and renal failure in the world.

1.1 Prevalence of Diabetes

Nowhere is the diabetes epidemic more pronounced than in India as the World Health Organization (WHO) reports show that 32 million people had diabetes in the year 2000 [5]. From the graphical figure 1 the International Diabetes Federation (IDF) estimates the total number of diabetic subjects in India is further set to rise to 69.9 million by the year 2025.

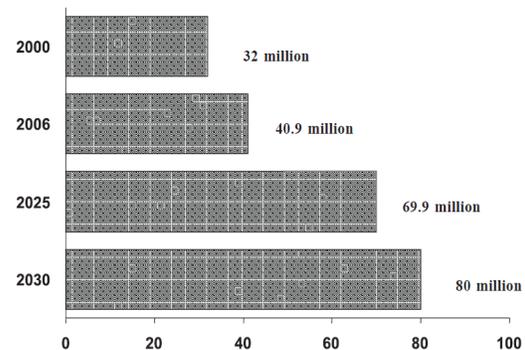


Fig.1 Estimated number of diabetic subjects in India

Source: Ref. [25, 26]

1.2 Classification of diabetes

Diabetes affects the body's ability to produce or utilize insulin, a hormone that is needed to properly process blood glucose. As a result, diabetics must regulate their own blood sugar levels through diet and insulin injections. The key point in the regulation of blood sugar is the accurate measurement of the blood sugar level. [6].

The classification of diabetes falls under three categories:

- DM type 1 results from the failure of body to produce insulin and therefore requires an injection of insulin. This type is most

preferably called as *insulin-dependent DM* (IDDM) or *juvenile diabetes*.

- DM type 2 results from insulin resistance, a simple condition in which cells fail to properly utilize insulin. Sometimes this condition may be assumed to be absolute insulin deficiency. This type is referred to as *non-insulin-dependent DM* (NIDDM) and also called *adult onset diabetes*.
- Gestational diabetes results when pregnant women whom never had diabetes before experience a substantial increase in blood glucose level during pregnancy. This condition may influence the development of type 2 DM [20, 21].

Other forms of DM include congenital diabetes (which occurs due to genetic defects of insulin secretion), cystic fibrosis-related diabetes, diabetes (steroidal) induced by high doses of glucocorticoids, and other forms of monogenic diabetes.

Although there is an increase in the prevalence of type 1 diabetes also, the major driver of the epidemic is the more common form of diabetes, namely type 2 diabetes, which accounts for more than 90 per cent of all diabetes cases [7].

All forms of diabetes have been treatable for an extent since insulin became available in 1921, and type 2 DM may be controlled with proper timely medications. Both type 1 and 2 DM are chronic conditions that usually cannot be cured but prevented to some extent. Transplantation of pancreas has been tried as a cure but only with limited success in type 1 DM whereas gastric bypass surgery has been successful in many with morbid obesity and type 2 DM. Gestational type of DM usually resolves after delivery. Diabetes without proper treatment can cause many complications. Acute complications include hypoglycemia, diabetic ketoacidosis, or nonketotic hyperosmolar coma. Serious long-term complications in

diabetes include more chances of cardiovascular disease, chronic renal failure, and retinal damage. Adequate treatment of diabetes is thus very important, in addition to controlling blood pressure control, taking care of lifestyle factors such as smoking, and maintaining a healthy body weight [20,21].

2. DIABETIC RELATED CAUSES

Cardiovascular disease is responsible for 80% of deaths among patients with diabetes, much of which have been attributed to coronary artery disease (CAD). CAD leads to atherosclerosis, which further narrows the blood vessel due to occlusion of the lumen. However, there is an increasing recognition that patients with diabetes suffer from an additional cardiac insult termed '**diabetic Cardiomyopathy**'.

Diabetic Cardiomyopathy refers to a disease process which affects the myocardium in diabetic patients causing a wide range of structural abnormalities eventually leading to LVH [left ventricular (LV) hypertrophy] and diastolic and systolic dysfunction or a combination of these. The concept of diabetic Cardiomyopathy is based upon the idea that diabetes is the factor which leads to changes at the cellular level, leading to structural abnormalities [2]. Diabetic Cardiomyopathy is a distinct primary disease process, independent of CAD, which leads to heart failure in patients with diabetes. Epidemiological and clinical trial data have confirmed the greater incidence and prevalence of heart failure in patients with diabetes [3].

Diabetic retinopathy (DR) is one of the most serious complications arising out of diabetes and a major cause of visual morbidity. Most screening programs use non-mydratic digital color fundus cameras to acquire color photographs of the back of the eye, the retina. These photographs are then examined for the presence of lesions

indicative of DR (including micro aneurysms, haemorrhages, exudates and cotton wool spots). Development of systems to automate DR screening have received a lot of attention from the research community [8]. At present, the classification of DR is based on the International Clinical Diabetic Retinopathy Disease Severity. There are five levels of DR severity, namely no DR, mild non-proliferative diabetic retinopathy (NPDR), moderate NPDR, severe NPDR and proliferative diabetic retinopathy (PDR). According to the Malaysia National Eye Database 2007, among 10,856 cases with diabetes, 36.8% has any form of DR, of which 7.1% comprises proliferative diabetic retinopathy (PDR). The determination of DR severity is important in treating the disease. At present, an International Clinical Diabetic Retinopathy Disease Severity Scale is used in grading of DR [1]. Using the International Clinical Diabetic Retinopathy Disease Severity Scale, an ophthalmologist needs to observe and determine DR-related abnormalities present in the color fundus image [9].

Diabetic Myonecrosis a rare complication of long-standing, poorly controlled diabetes mellitus typically presents with acute-onset muscle pain, is self-limiting, and responds well to conservative management. However, the prevalence of diabetes is increasing with sedentary lifestyles, poor diet, lack of exercise and an aging population; we can therefore expect the prevalence of diabetic Myonecrosis to increase along with that of other diabetes-related complications.

3. MEDICAL IMAGING & SURVEY OF IMAGE PROCESSING METHODS

3.1 Diabetic Cardiomyopathy

Although no single diagnostic test for diabetic Cardiomyopathy exists, using different imaging modalities it is possible to detect the phenotypic cardiac features of this condition. Currently used diagnostic

methods in clinical practice include echocardiography, cardiac MR and cardiac biomarkers such as NT-BNP [N-terminal pro-BNP (brain natriuretic peptide)]. Echocardiography is an excellent non-invasive and practical imaging tool for defining cardiac structure and function and allows 'real-time' visualization of the cardiac cycle. Quantitative and qualitative assessment of the heart can be made with regard to LV(left ventricular) geometry, regional wall motion, and systolic and diastolic function, in addition to valvular anatomy and function. Two-dimensional echocardiography has traditionally been the method of choice in detecting and quantifying LVH(left ventricular hypertrophy), and has been validated in the research and clinical setting. Pulsed-wave Doppler echocardiography is therefore the most practical and commonly used method [3].

The coronary angiography is an important examination for a diagnostic tool in cardiology. It is useful to precise diagnosis and treatment of patients to make an accurate analysis of vessel morphology on the angiogram. So it is necessary to extract vessels from the coronary angiogram. But usually there are several problems for extract vessels: weak contrast between the coronary arteries and the background, an apriority unknown and easily deformable shape of the vessel tree, sometimes overlapping strong shadows of bones and so on.

For the above said reason, it is clearly mentioned in [11] about importance of extracting the vessels. Even though the vessels are extracted as in [11] there is a need of analysis of the internal part of the blood vessels to make even a common man to understand the abnormality and severity of the disorder. The consideration of cross section of blood vessel images (also called as capillary basement membrane) obtained from Electron micrograph imaging modality as mentioned in [3] is the foremost

preference. Thickening of the capillary basement membrane leading to occlusion of lumen (as shown in Fig 2 has been reported in humans [34, 35] a way back but lack of availability of imaging methods and research on the concerned images have created an urgent situation to explicate the problem through easiest process.

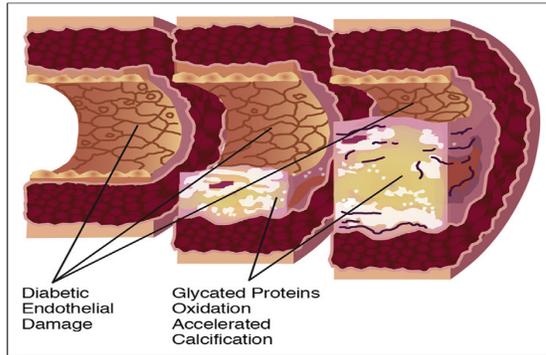


Fig.2 Lumen Occlusion in Blood Vessel

(Image Courtesy : Ref [31])

3.2. Diabetic Retinopathy

From visual inspection of Diabetic retinopathy (DR) images, exudates appear differently in a yellowish or white colour with varying sizes, shape and locations. They are often seen in either individual streaks or clusters or in large circinate structures surrounding clusters of micro aneurysms. At the same time, some of them are seen in varying sizes, shape and locations. The fundus photographs were taken with a non-mydratic fundus camera and were then scanned by a flat-bed scanner. The retinal image of the patient must be clear enough to show retinal detail. Low quality images (non-uniform illumination, low contrast, blur or faint image) do not perform well even when enhancement processes were included. The examination time and effect on the patient could be reduced if the system can succeed on non-dilated pupils. Furthermore, many techniques required intensive computing power for training and classification [10].

In an earlier study presented in [12-14], it has been shown that the

enlargement of Foveal avascular zone (FAZ) is correlated to the progression of DR stages. Digital image enhancement and analysis techniques were developed to enable the effective use of colour fundus images instead of fluorescein angiograms which requires injection of contrasting agents.

In a work carried in [9], a DR grading system based on colour fundus imaging of FAZ enlargement has been evaluated in an observational clinical study. They have used two methods of contrast enhancement used in the system, namely Contrast Limited Adaptive Histogram Equalization (CLAHE) and Independent Component Analysis (ICA) as pre-processing and as a post-processing used segmentation process which is based on Otsu's thresholding [15]. Further process conveys how the retinal blood vessel end points at perifoveal capillary network is detected and selected to determine the FAZ area. This is achieved by detecting all nearest points to the centre of macula. The FAZ area is formed by connecting the detected points that encircle the perimeter of macula. In the last step, a Gaussian Bayes classifier is used to determine DR severity based on the measured FAZ area (in pixels) obtained from digital colour fundus images.

In 2008 Aliaa et al. [17] introduced Optic disc (OD) detection for developing computerized screening systems for diabetic retinopathy. The OD detection algorithm was based on matching the usual directional pattern of the retinal blood vessels. Hence, a simple matched filter is projected to roughly match the direction of the vessels at the OD vicinity of retina image.

In 2010, Xu and Luo [18] presented a technique that uses adaptive local thresholding to produce a binary image, and then extract bulky connected components as large vessels. The residual fragments in binary image including some

slight vessel segments were classified by support vector machine. In 2010, Faust et al. [19] presented algorithms for an automated recognition of diabetic retinopathy by means of Digital Fundus images; retina images affected diabetes and normal are classified using characteristics such as blood vessel area, exudates, haemorrhage microaneurysms and texture extracted from retina image and supplied to the classifier.

In 2011, Vijayamadheswaran et al. [20] presented detection of diabetic retinopathy using radial basis function. The algorithm uses features obtained from the retina images captured through fundus camera. Contextual Clustering (CC) segmentation technique is used for classification of retina images. In 2012, Joshi and Karule [21] discussed Retinal Blood Vessel Segmentation. The fundus RGB image was used for obtaining the traces of blood vessels. The algorithm generated uses morphological operation to smoothen the background, retaining veins. In 2012, Selvathi et al. [22] presented computerized detection of diabetic Retinopathy for early diagnosis using feature extraction and support vector machines. The features considered are blood vessels, exudates & microaneurysms in training set and in test image.

In 2013, Badsha et al. [24] presented automated method to extract the retinal blood vessel. The proposed method comprises several basic image processing techniques, namely edge growth by standard template, noise removal, thresholding, morphological operation and entity classification. In 2013, Nidhal et al. [25] introduced blood vessel segmentation using mathematical morphology in fundus retinal images. The method uses RGB retina image and separates Green channel from RGB image which gives good details. Retinal images are normally noisy and non-uniform illumination. So contrast

limited adaptive histogram equalization is used for contrast improvement. The Top-Hat transform is used for withdrawal of small details from given image. In 2013, Kavitha and kumar [26] presented edge detection for retinal image using Superimposing concept and Curvelet transform, which makes the edge recognition effectively. Back propagation algorithm is used for blood vessel detection which helps to find out the real retinal blood vessels from the image to generate the better result. In 2013, Rashid and Shagufta [27] presented automated method to detect exudates from low contrast images of retinopathy patient's with non-dilated pupil using features based Fuzzy cmeans clustering method with a combination of morphology techniques & pre-processing to improve the strength of blood vessels and optic disk detection.

In 2014, Jeprins and Sundari [28] presented Diabetic retinopathy, and also cardiovascular diseases like ophthalmic pathologies, hypertension. The work examined the blood vessels segmentation of two dimensional retinal images acquired from a fundus camera.

Exudates are a visible sign of diabetic retinopathy, which is the major source of blindness in patients with diabetes. If the exudates expand into the macular area it might lead to visible morbidity. Automated early detection of the presence of exudates can assist ophthalmologists to prevent the spread of the disease more efficiently. Hence, the detection of exudates is an important diagnostic task. T.Vandarkuzhali et al. presented an automated system to detect different abnormalities due to diabetic retinopathy in retinal images in [16] and the work was chiefly about exudates. A conceptual idea of fuzzy logic and neural network is applied to distinguish the abnormalities in the fovea. Normal retinal images as well as affected images were

used in this work. This system is simple and efficient in extracting whether the picture is normal or abnormal state.

3.2.1 Publicly available retinal image databases

A summary of all the publicly available retinal image databases known to us is given in this section. Most of the retinal vessel segmentation methodologies are evaluated on two databases (DRIVE and STARE). The DRIVE (Digital Retinal Images for Vessel Extraction) is a publicly available database, consisting of a total of 40 color fundus photographs.

DRIVE Database

The photographs were obtained from a diabetic retinopathy screening program in the Netherlands. The screening population consisted of 453 subjects between 31 and 86 years of age. Each image has been JPEG compressed, which is common practice in screening programs. Of the 40 images in the database, 7 contain pathology, namely exudates, hemorrhages and pigment epithelium changes. The images were acquired using a Canon CR5 non-mydratic 3-CCD camera with a 45° field of view (FOV).

STARE database

The STARE database contains 20 images for blood vessel segmentation; ten of these contain pathology. The digitized slides are captured by a TopCon TRV-50 fundus camera at 35° field of view. The slides were digitized to 605 × 700 pixels, 8 bits per color channel. The approximate diameter of the FOV is 650 × 500 pixels.

ARIA online

This database was created in 2006, in a research collaboration between St. Paul's Eye Unit, Royal Liverpool University Hospital Trust, Liverpool, UK and the

Department of Ophthalmology, Clinical Sciences, University of Liverpool, Liverpool, UK . The database consists of three groups; one has 92 images with age-related macular degeneration, the second group has 59 images with diabetes and a control group consists of 61 images. The trace of blood vessels, the optic disc and fovea location is marked by two image analysis experts as the reference standard. The images are captured at a resolution of 768 × 576 pixels in RGB color with 8-bits per color plane with a Zeiss FF450+ fundus camera at a 50° FOV and stored as uncompressed TIFF files.

ImageRet

The ImageRet database was made publicly available in 2008 and is subdivided into two sub-databases, DIARETDB0 and DIARETDB1. DIARETDB0 contains 130 retinal images of which 20 are normal and 110 contain various symptoms of diabetic retinopathy. DIARETDB1 contains 89 images out of which 5 images are of a healthy retina while the other 84 have at least some signs of mild proliferative diabetic retinopathy.

Messidor

The Messidor-project database is the largest database of 1200 retinal images currently available on the internet and is provided courtesy of the Messidor program partners. The images were acquired at three different ophthalmology departments using a non-mydratic 3CCD camera (Topcon TRC NW6) at 45° FOV with a resolution of 1440 × 960, 2240 × 1488 or 2304 × 1536 pixels and are stored in TIFF format. Out of 1200 Images 800 are captured with pupil dilation.

Review

The Retinal Vessel Image set for Estimation of Widths (REVIEW) was made available online in 2008 by the

Department of Computing and Informatics at the University of Lincoln, Lincoln, UK. The dataset contains 16 mydriatic images with 193 annotated vessel segments consisting of 5066 profile points manually marked by three independent experts

ROC microaneurysm set

The ROC microaneurysm dataset is part of a multi-year online competition of microaneurysm detection that was arranged by the University of Iowa in 2009. The database consists of 100 digital color fundus photographs containing microaneurysms and is subdivided into a training set of 50 images and a test set of 50 images.

VICAVR database

The VICAVR database is a set of retinal images used for the computation of the A/V ratio. The database currently includes 58 images. The images have been acquired with a TopCon nonmydriatic camera NW-100 model and are optic disc centered with a resolution of 768×584 .

3.3 Diabetic Myonecrosis

Diabetic Myonecrosis is a rare complication of diabetes mellitus. Only approximately 100 cases have been published [29]. The prevalence of various complications increases with the duration of diabetes; thus, this rare complication may be encountered in patients with long-standing diabetes. Typically, it presents as acute-onset muscle pain, localized in the lower limb. The clinical features of diabetic Myonecrosis are nonspecific; therefore, its diagnosis and treatment are often delayed.

Imaging has an important role to play in the non-invasive diagnostic evaluation of skeletal muscle necrosis. Though plain radiography, ultrasound, and CT can serve to locate the site and extent of the lesion, the imaging features of these modalities

are not specific. Reports of MRI features of skeletal Myonecrosis exist [30], but an extensive research using Image processing methods doesn't exist in Literature.

Thus lot of scope for researchers belonging to imaging technologies has been created to investigate the methods on MRI images related to Diabetic Myonecrosis.

4. CONCLUSION

It is observed from the literature review carried out above; a lot of imaging methodologies work is implemented on Diabetic Retinopathy. However it is a challenge to the researchers to put lot of efforts to investigate on other related problems. Thus as a part of this research work Cardiac and Myonecrosis anomalies are considered for investigation.

ACKNOWLEDGEMENT

The authors are thankful to SunRise University-Alwar, Rajasthan and Annamacharya Institute of Technology & Sciences, Rajampet, A.P. for providing research facilities. And also thankful to Dr.B.Jayabhaskar Rao, Diabetologist, Diabetic Care Center Nandalur, A.P. for providing the detailed explanation of Diabetes and its abnormalities.

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