CHAPTER 2

RELATED WORK AND LITERATURE SURVEY

2.1 INTRODUCTION

The literature survey of the related works has been carried out throughout the research with an intention to comprehend the ideas of identifying the diabetic retinopathy from various sources using different methodologies and to investigate the performance analysis of the proposed methodology. This section categorizes works related to Biometric Authentication systems, Multimodal Biometric systems, Using of Textures as Features, Application of LBP operator and using SIFT algorithm to integrate a novel feature extraction technique that makes the model robust.

2.2 DETECTION OF ABNORMAL VESSELS

Pallawala et al. (2004) and Wynne Hsu et al. (2004). In their proposed work they extracted a total of 990 main vessel segments out of 300 retinal images. To determine whether the vessels are tortuous, the center lines of the extracted vessels and the curvatures are tabulated.

Adilson et al. (2002) observed that the features of contraction and dilation of the pupil have some person-to-person differences, both during the contraction time (visible light on) and the dilation time (visible light off). Then, it is supposed that the pupil circularity, diameter, contraction/dilation time and contraction / dilation rate be individual features and have discrimination power between different individuals. The circularity and the
diameter are extracted in each one of the 5 periods of time. The time and the contraction/dilation rates are measured under illumination alteration conditions. Presents a different graph for the diameter of the pupil during an example video sequence. The pupil contracts more in the first light pulse – between frames 210 and 220 – than between frames 630 and 640. The individual average for this variation is utilized as positions of the feature vector. Figure 2.1 depicts the variation of the pupil diameter

![Figure 2.1 Pupil diameter variation](image)

## 2.3 DETECTION OF MICROANEURYSMS

The proposed work exploited the feature and used the top-hat transform to produce candidate micro aneurysms. The true micro aneurysms were then pruned by using post-processing based on their earlier work and classification. The candidate micro aneurysm segmentation was conducted using a grouping of top-hat transform and matched filtering with region growing. To improve the sensitivity of the applicant search a shade correction and dynamic range normalization steps were introduced in the pre-processing. After detection and segmentation of the applicant micro aneurysms, the true
micro aneurysms were pruned from the spurious responses using a rule-based classifier with a number of shape and intensity based features. By using the computer vision based detection concept (i.e. image acquisition, pre-processing, applicant object segmentation and classification) Spencer et al. achieved a better control over the problem and allowed the easier development of variant methods. (Spencer et al. 1996) The Figure 2.2 shows the detection of micro-aneurysms.

![Micro aneurysms](image)

**Figure 2.2 Micro aneurysms**

The main difference between the method proposed by Spencer et al. and the variant methods lay in the classification step, where similar classifiers and features were used. The feature and classification selection was also studied in Ege et al. (2000). The intravenous use of the fluorescein restricts the use of fluorescein angiography in large scale screening that turned the interest of researchers towards the red-free and colour eye fundus photography. Unlike in the fluorescein angiograms, the micro-aneurysms appear dark in the red-free and colour eye fundus images, and have lower contrast. Otherwise the detection task is, however, quite similar. Based on the research a version of the top-hat transform based method was presented for red-free images by Hipwell et al. (2000) and for colour eye fundus images by Yang et al. (2015) and Fleming et al. (2006).
Klein et al. (2011) An alternative mathematical morphology based approach was proposed by them to overcome a shortcoming of the top-hat based methods: the linear structuring element at discreet orientations tended to detect tortuous vessels as candidate micro-aneurysms. Instead of using linear structuring element, a bounding box closing was applied with the top-hat transform. Since the candidate object detection of the top-hat transform based methods also missed number of true micro-aneurysms. (Niemeijer et al. 2007) proposed a red lesion (micro-aneurysm and hemorrhage) detection algorithm by introducing a hybrid method to relax the strict candidate object size limitations. Figure 2.3 shows the image of the retina which has undergone hemorrhage.

A combination of the top-hat based method described in and a pixel-based classification scheme was proposed to produce a more comprehensive set of candidates. After detecting candidates the true red lesions were pruned in k-nearest neighbor classification. There are also amount of approaches for micro aneurysm detection published in literature that are not based on morphological operations.

![Figure 2.3 Hemorrhage](image)

One of the first approaches applied in detection diabetic retinopathy was proposed by (Gardner et al. 1996) who conducted introduction experiments to study whether neural networks can be used in screening diabetic retinopathy. The neural network and supervised learning
was utilized on red-free eye fundus images to extract the micro aneurysm and hemorrhage characteristics from set of image patches. Using the skilled neural network the micro aneurysms and hemorrhages were located from before unseen set of test images.

Kamel et al. (2008) have proposed a similar method for fluorescein angiograms to substitute the slow intermediate filtering sequences in the before described top-hat transform based methods.

The approaches are assumed that dark areas in the color eye fundus images consist of vessels, micro aneurysms and hemorrhages. By excluding the vessels and vessel segments, the remaining items could be identified as micro aneurysms and hemorrhages.

Sinthanayothin et al. and Usher et al. (2002) They used recursive region growing to cluster the dark areas in the image and classified the vessel and vessel segments from the region growing result using a neural network. (Grisan & Ruggeri 2007) In their work they detected dark objects by clustering similar pixels with high local spatial density. The method was further improved by (Garcha et al. 2008, 2009) who added an automatic feature selection and classification step (neural networks) to prune the true red lesions.

Pallawala et al. (2004) A distinct approach has been proposed in which the micro-aneurysm detection was defined as a segmentation problem between micro-regions (i.e. microaneurysms) and the background regions (i.e. other eye fundus structures). The graph theory-based segmentation procedure exploited the similarity and spatial proximity of image pixels to cluster small tightly grouped areas into one category and more loosely connected larger areas into the other. In the post-processing step, the true microaneurysms
were pruned from the small tightly grouped areas using the intensity difference between the area and the immediate surroundings.

Xiaohui and Chutatape et al. (2006) extracted the typical features of hemorrhages from image templates using the Principal Component Analysis (PCA). The extracted features were used with the support vector machine to classify the image patches of before unseen color eye fundus image. To detect the different sized hemorrhages, a pyramid of images was generated by computationally varying the image resolution. Quellec et al. (2008 and 2010) also used image templates in detection of microaneurysms by conducting template matching in wavelet domain. (Bhalerao et al. 2008) In this proposed method he modeled the circular shape and darker appearance of microaneurysms by combining the Laplacian of Gaussian and circular-symmetry operator in filtering the candidate microaneurysms.

A template from each candidate microaneurysm location was extract to find the true microaneurysms using a PCA-based region analysis. A different approach was proposed by Narasimha-Iyer et al. (2003) by introducing the use of temporal changes between color eye fundus images to detect the symptoms of diabetic retinopathy. First, the images were pre-processed by registering the images with the dual-bootstrap iterative closest point algorithm, correcting the clarification using the iterative homomorphic surface fitting, and removing the dust particles using the ratio of the green and red reflectance components. The difference of two pre-processed eye fundus images were then classified to change and no-change regions and further to lesion categories including micro aneurysms and hemorrhages based on the difference ratio values.

Diabetic retinopathy (DR) is one of the most common micro vascular complications and its early detection is critical for the prevention of vision loss. Recent studies have indicated that microaneurysms (MAs) are the
hallmark of DR. However, the detection of MAs relies on trained clinicians and relatively expensive software. Moreover, manual errors often lower the accuracy of this detection. Therefore, an automatic analysis technique is highly demanded in the detection of DR progression. This paper presents a novel and complete methodology involving two different ways from the view of MAs turnover and pathological risk factors to diagnose the progression of DR. Specifically, one approach follows the traditional image analysis-based roadmap to obtain MAs turnover. The other investigates seven pathological features, related with MAs turnover, to classify the unchanged, new, and resolved MAs by means of statistical analysis and pattern classification techniques. The evaluations on Grampian diabetes database show that the proposed image analysis method could achieve a sensitivity of 94% and a specificity of 93%, while the classification model could achieve 89% sensitivity and 88% specificity, respectively. (Jiawei Xu et al., 2017)

2.4 HARD AND SOFT EXUDATES

The early work in the automated detection of hard and soft exudates generally investigated possibilities of thresholding techniques. (Ward et al., 1989). In his proposed work a semiautomatic exudates detection system based on shade correction and thresholding, where the user interaction was required in the thresholding.

By introducing a dynamic thresholding procedure Philips et al. (2005) and Zheng et al. (2010) have suggested a considerable improvement to the previous system. Philips et al. (2005) detected large high intensity areas from red-free eye fundus images using a global thresholding scheme, whereas a block-wise local thresholding was applied to segment the smaller exudates. The method was able to produce relatively good results in detecting the exudates pixels, but at the same time an unacceptable number of false
positives were generated. As a result, the ophthalmologic expertise was required in the interpretation of the detection results.

To counter the false positives, Zheng et al. (2010) have introduced the use of local neighbourhood in the dynamic block-wise local thresholding method that was later adopted by Sagar et al. (2007). (Goldbaum et al. 1996, 2003) In this work with the early thresholding, proposed a bright lesion detection approach based on template matching and edge detection. By computationally sampling the image resolution and apply the template matching, the bright lesions of all sizes were located. The outlines of each located lesion were refined using edge detection.

Goldbaum et al. (2003) In the work, the sub-classes of bright lesions were considered, i.e. hard and soft exudates that should be differentiate for the diagnosis of diabetic retinopathy. For the identification, a spherical colour space was introduced. From template matching and thresholding, the method development turned towards supervised statistical pixel-based lesion classification. The first pixel and block-based classification approaches utilized a simple minimum distance discriminate classifier to classify image pixels into two classes (i.e. to bright lesion and background) according to their pixel value.

Wang et al. (2000) In the proposed work, the minimum distance discriminate classifier has been he applied in the colour space as suggested by (Goldbaum et al. 2003) to detect candidate hard exudates pixels. The true hard exudates pixels were then pruned using the compare information of the local neighbourhood. (Sancheza et al.2009) In their work they further developed the method using alternative approaches for the non-uniform illumination correction and hard exudates pixel pruning. (Goh et al. 2000) In this proposed
system, the minimum distance discriminate classifier has been applied directly in RGB colour space to detect hard exudates pixels.

Niemeijer et al. (2007) In the work a pixel classification scheme based on k-nearest neighbour classification to detect and separate hard and soft exudates has been proposed. The system searched for candidate bright lesion pixels according to the features selected in the preparation stage. By using the density of classified lesion pixels among the neighbouring pixels in the feature space, a lesion probability was assigned for each pixel in the test image. The high probability regions were pruned to find the true bright lesions by extracting descriptive features for each region and applying the KNN classification once again. Finally, a linear classifier was used to classify the detected true bright lesions to hard and soft exudates and druses. (Sanchez et al. 2009) To improve the hard exudates detection, the work introduced the use contextual information, i.e. the spatial relations of the surrounding anatomical structures and similar lesions.

Xu et al. (2007) A feature-based classification scheme was proposed by where a feature combination based on stationary wavelet transform and gray level co-occurrence matrix was used to characterize the textural properties of hard exudates. The pixel level classification was conducted using a support vector machine. (Sinthanayothin et al. 2002) Another support vector machine-based approach was proposed where the local textural properties were extracted using a Scale-Invariant Feature Transform (SIFT).

Given the irregular properties of hard exudates in shape and scale, the pixel- and block based clustering methods provided another strong approach for local segmentation of hard exudates. (Hsu et al. 2004) In his work he utilized dynamic clustering after shade correction to group the image
pixels into (bright) lesion and non-lesion areas. The hard exudates clusters were differentiated from other bright lesions based on the contrast difference between the (bright) lesion and non-lesion classes.

A more elaborate clustering technique was proposed by him, (Osareh et al. 2002 and 2003) where the candidate object detection was based on Gaussian-smoothed histogram analysis and Fuzzy C-Means (FCM) clustering. The idea was to use the Gaussian-smoothed histogram analysis to coarsely cluster the image according to the important extreme points in the image histogram. The FCM clustering was then used to allocate the remaining unclassified pixels to the previously determined clusters.

To indentify the hard exudates regions from the non-hard exudates regions image features were extracted from the clustered regions and then classified using a neural network approach. Zhang et al., 2006 further improved the FCM method to exploit information in the neighboring pixels to decrease the effect of the image noise.

Ramlugun et al. (2012) has studied a clustering scheme, where two feature spaces were composed by combining color channels of different color spaces. The purpose was to construct two divergent feature spaces descriptive for different eye fundus structures. First, the k-means clustering was used on both feature spaces to group similar image pixels and then by using reasoning and the complementary performance of the feature spaces, a set of candidate hard exudates regions were selected from the clustering results. To suppress false positives, the color information of the candidate regions before and after the color channel de-correlation method was exploited.

Ravishankar et al. (2009) had applied morphological operations to contain the blood vessel network and to emphasize the bright lesion boundaries by dilating the image at two different scales and subtract the
outcomes. By using dynamic thresholding and morphologic filling, the candidate exudates were extracted from the dilation result by finding the connected regions within the emphasized lesion boundaries. In the final stage, brightness and edge properties of the candidate regions were used with the rule-based classification to establish the true hard exudates regions.

Kavitha et al. (2009) had a very similar approach without the final classification step and with the dynamic thresholding step substituted to edge detection with the Laplacian of Gaussians.

2.5 AUTOMATIC DETECTION OF DIABETIC RETINOPATHY

Goldbaum et al. (1996) had proposed a methodology in which an image-explanation language was utilized to symbolize the properties of lesions and normal structures in eye fundus images. By using a neural network and a set of representative images of known diagnosis, the connection between the image description information and the known diagnosis was learned. Based on the training data, the trained network was able to detect images with diabetic retinopathy using the image description information derived from the result of automatic eye fundus image analysis system. Youssif et al. (2007) Instead of using image descriptions, the work utilized neural networks with wavelet coefficients to train the network using cluster centroids obtained from channel-wise fuzzy c-means clustering, and the work utilised shape related features extracted from the segmented vessel and lesion regions.

Fleming et al. (2006) The proposed work have utilized their earlier experiences with the microaneurysm detection in and introduced an inversion of the morphological top-hat technique to detect hard exudates. A linear structuring element at different orientations and scales were applied with the
top-hat transform to emphasize bright regions in the image. By using a
dynamic thresholding scheme the candidate exudates were extracted from the
top-hat result and finally classified to exudates, drusen and background
according to their color, shape, brightness and the contrast variation to the
local background. The use of contextual information in the form of distance to
the closest microaneurysm was also studied.

Another feature-based classification scheme based on machine
learning was proposed by Agurto et al. (2012), where the regular and
pathological structures were characterized according to their amplitude and
frequency content, conceptually, describing the textural properties. After
decomposing the image using the Amplitude Modulation – Frequency
Modulation (AF-FM) decomposition and extracting the textural features for
each image from several image locations, k-means clustering was used to
cluster the extracted features into several groups. The number of textural
features in each of the group defined the final descriptor for each image.
Using the describe descriptors and a partial least square classifier, the
presences of diabetic retinopathy was detected in eye fundus images.

Niemeijer et al. (2000) The work studied the use of multiple
information sources and their fusion to achieve more robust detection for
screening diabetic retinopathy. The proposed system analyzed two images per
eye and four images in total to produce a subject-wise score value that
indicated the likelihood that the test subject needs to be examined by a human
observer. Each of the four images were separately analyzed with complex
Computer Aided Detection or Diagnosis (CAD) system to establish the image
quality and the diabetic lesion locations (red and bright lesions). The subject-
wise score value was then combined from the outputs of the CAD systems
and based on the score value the diabetic retinopathy was detected in eye fundus images.

Sohini Roychoudury et al., (2017) The work presents a novel classification-based Optic Disc (OD) segmentation algorithm that detects the OD boundary and the location of Vessel Origin (VO) pixel. First, the green plane of each fundus image is resized and morphologically reconstructed using a circular structuring element. Bright regions are then extracted from the morphologically reconstructed image that lies in close vicinity of the major blood vessels. Next, the bright regions are classified as bright probable OD regions and non-OD regions using six region-based features and a Gaussian mixture model classifier. The classified bright probable OD region with maximum Vessel-Sum and Solidity is detected as the best candidate region for the OD. Other bright probable OD regions within 1-disc diameter from the centroid of the best candidate OD region are then detected as remaining candidate regions for the OD. A convex hull containing all the candidate OD regions is then estimated, and a best-fit ellipse across the convex hull becomes the segmented OD boundary. Finally, the centroid of major blood vessels within the segmented OD boundary is detected as the VO pixel location. The proposed algorithm has low computation time complexity and it is robust to variations in image illumination, imaging angles, and retinal abnormalities.

Fleming et al. (2006) had a related idea, where eye fundus images of both eyes were first analyzed for micro aneurysms, hemorrhages, hard exudates and image quality and by using the output several image-based lesion measures were computed and combined into overall subject-wise score. Similarly as previously, the score value was used to detect the patients with referable diabetic retinopathy.
2.6 NOVEL FUZZY RULES

Fuzzy Association Rule uses fuzzy logic to convert numerical attributes to fuzzy attributes thus maintaining the integrity of the information conveyed by such numerical attributes was suggested by Rajendran et al. (2012). The popular fuzzy association rule mining algorithms that are available today are fuzzy apriori and its different variations. Fuzzy apriori algorithm has been well supported for the numerical analysis, but where as in medical image classifications it is less efficient. In paper, the concepts of data mining are described which includes the different types of basic algorithms used for mining all explained briefly. It also includes the most popularly used Association rule mining algorithm called Apriori algorithm and its basics. In paper (Alireza Osareh et al. 2001) Association rule mining and efficiency in large database has been employed. The basic concepts of digital image processing applied in the field of Image mining and also the feature extraction techniques like gray level and histogram equalization are given. The details of regions of interest and also the algorithm used like watershed and Water immersion algorithm are discussed in detail. Most of the immersion algorithm is given in detail. Most of the fuzzy ARM work are directed towards theoretical aspects of finding, both positive and negative ones. (Adam Hoover et al. 2003) (Adel et al. 2010). Fuzzy Apriori, the de facto algorithm used for fuzzy association rule mining is used in (Alireza Osareh et al. 2003). In order to crate fuzzy partitions from datasets, points that are belonging to different clusters are given in Chaudhuri et al., (1989). A Multimedia data mining system prototype multimedia miner uses a data cube structure for mining characteristic, association and classification rules. Discovering association rules algorithm based on image content from a simple image dataset is presented. Research in image mining can be broadly classified into two main directions. The first direction involves domain-specific applications.
Figure 2.4 describes about the fuzzy partition on image domain with different attribute values. As a result the extended attribute value is in the interval [0,1] is changed from the original datasets is the transactional database for forming the NFARM rules. In order to process this dataset, new procedures are used in terms of t-norms. The generation of NFARM is directly impacted by the fuzzy measures.

![Fuzzy partitions on image domain](image.png)

**Figure 2.4 Fuzzy partitions on image domain of different attribute values**

The pseudo-code for forming the NFARM rules is depicted below

**Pseudo-Code for forming NFARM Rules**

1) traverse each partition P
2) for each itemset it to P in 1st phase
3) if it is frequent(based on count[it]) over the whole database E
4) output(it)
5) remove it
6) for each remaining itemset it
7) identify constituent singletons s1, s2, …, sm of it it = s1
_ s2....._ sm

8) tidlist td[it] = intersect tidlists of all constituent singletons

9) calculate μ for it using td[μ t]

10) count[it] += μ

11) if no itemsets remain to be enumerated

12) exit

Goh et al. (2001) combined several classifiers to detect diabetic retinopathy from eye fundus images by following the main principal of classifier ensembles, i.e. while the single best performance is achieved using the best classifier, the misclassified samples by the best classifier are not necessarily misclassified by rest of the classifiers. A set of nine ensembles containing several classifiers were construct, where three classifier ensembles were used for the background, four for the blood vessel and three for the bright lesion detection. The classifiers within each ensemble were based on neural networks. By using decision rules, the classifier outputs within each ensemble and the resulting ensemble outputs were combined into single label representing background, blood vessel or bright lesion. Each sub-image in the image was assigned with such label and based on the image patches containing bright lesions the presence of diabetic retinopathy was finally detected.