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Detection of Glaucoma using Machine Learning Approach

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Abstract: Conventional clinical diagnosis is often expensive, time-consuming, dependent on expert interpretation, and not readily available in primary healthcare settings. This study proposes an automated computer-aided diagnosis system for detecting and analysing retinal defects using fundus images. The proposed hybrid framework focuses on multiple anatomical and pathological structures, including retinal blood vessels, optic disc, and exudate lesions. Image pre-processing techniques are employed to enhance retinal images and extract relevant regions of interest. Retinal vessels are segmented using a Fully Connected Conditional Random Field (FC-CRF), followed by supervised classification using SVM and KNN. Optic disc and exudate lesions are segmented using mathematical morphology, fuzzy-set theory, and adaptive thresholding. The proposed system aims to support efficient, automated, and reliable screening of glaucoma and diabetic retinopathy (DR), particularly where limited training data and clinical resources are available.

Keywords: Glaucoma, Fuzzy Logic, Machine Learning, Eyes, Diabetes.

I.INTRODUCTION

Intraocular pressure increases due to hypertension or malfunction of eye drainage system, a liquid aqueous humor flows in between cornea and lens and vitreous humor present in rare part of eye ball. If pressure continues it damages optic nerve head, glaucoma will cause everlasting vision lost. Without treatment, glaucoma can cause total permanent blindness within a few years. Glaucoma naturally occurs equally in both eyes, but it can occupy each eye to a different level. Glaucoma cannot be prevented, but if it is diagnosed and treated early, the syndrome can be restricted. Once glaucoma occurred, vision loss is irrevocable and cannot be restored. In case of diabetic retinopathy (DR), the symptoms and signs are the same as glaucoma but due to diabetes the glucose in blood increases rapidly which affect the retinal blood vessels. In more severe cases means proliferative diabetic retinopathy (DR) damaged blood vessels cutoffs due to new growth of unwanted abnormal blood vessels in the retina producing scar like cotton wool like red and yellow spots it interferes the liquid flow in the eye which increases intra ocular pressure and damages optic nerve head resulting glaucoma.

Limitations of Clinical Glaucoma Tests

- It is expensive to detect glaucoma
- Not feasible for small babies and pregnant ladies
- It is time consuming process
- For diabetic patient routine checkup is required
- Use of eye drop for ophthalmoscopy had several hours blurred vision
- Glaucoma testing is unavailable at primary health centers
- Possibility of errors in detection due to human intervention
- Lack of social awareness

Motivation

In study of researchers they estimated that most of the world is suffering from glaucoma [5, 6]. The fundus photo graphs is extensive medical imaging technique and it is used to detect eye related disease this is due to non-invasive technique and easy to perform as they are computer aided system [7].The manual analysis is very time consuming process because ophthalmologist had to perform and check many fundus images with different levels of parameters and further more diagnosis may vary with one expert with another on their experience and techniques [8].Automated computer aided system generally consisting retinal vessels segmentation as we know in many eye disease retinal blood vessels affected due to raise in intraocular pressure and in diabetic retinopathy (DR) system screen exudates lesions and in some glaucoma cases ratio of optic cup to disc is also significant to monitor [9]. Most of the current methods are developed to scan and monitor characteristics of ONH which are affected by an eye disease [10]. Nowadays deep learning process is also giving extra ordinary detection results once they learn itself on the basis of different features of disease without manual intervention the features are collectively labelled and classified during the training phase [11]. Diabetic Retinopathy (DR)

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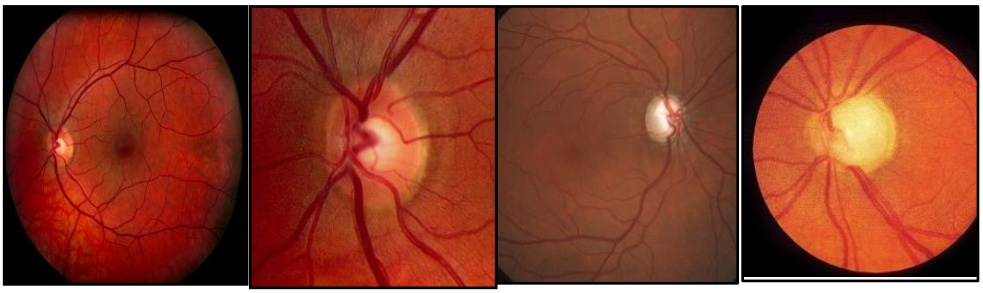
is a type of disease in which no early symptoms are traced out. For human observer it is hard to find and analyse initial stage of DR as it appears in the form of small red lesion observer can't generalize lesion properties which vary with time and physical characteristics of patient. Hence we discussed earlier deep learning technique which is a best and suitable technique to overcome from manual testing for diabetic retinopathy (DR) but this automated deep learning based systems is limited based on trained data, the data collection and learning classifiers on the basis of red lesions detection is tremendously high as it requires manual annotations and labels for specific structures. We have to devise a system which can work in condition where we are having limited number of trained data.

II.COMPUTER AIDED DIAGNOSIS

Computer aided diagnosis system plays a vital role to take secondary opinion about eye disease correlating with clinical findings. The results of computer aided diagnosis works qualitatively and quantitatively, the decision and opinion is considered as final because it is automated system in finding of disease. The computer based automated results are subjective for final judgment. Computer based diagnosis system works on different image processing techniques, basically it is based on three phases, and first one is image pre-processing. In this different image enhancement techniques are used to enhance the image or simply extract useful information from an image. Second is image quantification means image analysis is done using histogram, segmentation, filtering, morphological quantification and finally processing in last phase classification is done to make decision in normal and abnormal patterns.

Problem Definition

The main objective is retinal image analysis to produces qualitative results for the clinical assessment. Ophthalmologist needs both qualitative and quantitative impressions of retinal vessels, optic nerve head and exudates lesions. To diagnosis eye disease and to make baseline decisions in changes of retinal structure and characteristics may be detected by examination. We focus on two sight intimidating disease glaucoma and diabetic retinopathy (DR) is assessed in our work to detect and identification for preventing from further complication or vision loss. Mainly glaucoma occurs due to intraocular pressure of eye. It increased in patients who had high blood pressure, diabetes, previous eye surgeries, and Eye injuries and over dosage of steroid. In some cases of glaucoma vessels are not affected but optic cup to disc ratio will be vary but during optic disc and cup to ratio measurement in some patient's ratio is low and visual filed is lost in contrast cup to disc ratio is more than normal range also visual filed lost. In many cases retinal blood vessels and optic cup to disc ratio is in normal condition but due to inflammation or diabetes there is development of micro aneurysms or haemorrhages after certain time period vision is lost.



(a) (b) (c) (d)

Fig 1 a: Normal Eye Fundus b: Normal Optic Disc Fundus c: Glaucoma Fundus d: Glaucomatous Optic Disc (source-medicine.uiowa.edu and imagebank.asrs.org)

Diabetic Retinopathy (DR)

Retinal screening is important in today's life to detect retinopathy of prematurity in early stages before it goes sever, and these are sight threatening diseases.



(a) (b)

Fig 2: (a) (b) Fundus Images of Diabetic Retinopathy

Aim and Scope of Research

Our goal is to provide Automated Detection and classification of Eye related disease several research persons designed automated detection framework. Here we are developing a system which is capable to all structures in a single system, earlier for identification & segmentation each requiring standalone system and they are incapable to show the images of retina that contains any kind of pathological abnormalities due to some abnormal and dense structures like haemorrhages lesions and exudates. To overcome this difficulty, we initially work on retinal vessel segmentation using fully conditional random filed, the advantage of this technique is, we get structured prediction where a classifier predicts bypassing neighbouring samples as we know retinal structures had a dense potential. After segmentation we classify them, we used supervised classification and mainly we work on support vector machine and K-Nearest Neighbour. After vessel segmentation we work on optic disk and exudates lesions. Here we used unsupervised classification techniques. We combine mathematical morphology and fuzzy sets theories, here segmentation is done through adaptive fuzzy thresholding. In this hybrid system we combine three segmentation systems Retinal Vessel segmentation, Optic Disc segmentation and Exudates Lesion segmentation.

Objectives of Present Work

The study carried out on the basis of objectives mentioned bellow

- To study different eye Disease and their effect on human eye.
- To detect different pathological structure.
- To perform Image preprocessing on fundus images to get region of interest like ROI of retinal vessel.
- To study FC-CRF model as a recent one for vessel segmentation purpose.
- To study supervised classification SVM and K-NN classification technique for better results.
- To study segmentation with FCM clustering.
- To design automated system for detection and segmentation of eye related disease for multi anatomical structure of human eye.

III.LITERATURE REVIEW

A retinal Vessel property is the important aspect for any analysis system as it is capable to characterize features for glaucoma, even if conflicting results. Generally, o three retinal vascular characteristics are related with glaucoma: the calibre, angle of branching and the tortuosity of the retinal vessels. It is observed that person having glaucoma had extensively minor arteriolar and venular calibres than with normal person in numerous studies [1]. Rotterdam suggests that there is no connection in between retinal vascular calibre and glaucoma [2]. Arend find in his study FA also had to a same conclusion [3]. After all, glaucoma is mainly related with decrease in artery, tortuosity in veins and narrowing in branching angle of veins [4]. Retinal Vessel calibration and fractal dimension features are important aspect in early identification of proliferative & plain DR. It is observed in a larger retinal venular calibre with normal persons who have no manifest retinopathy as observed in diabetic patients with retinopathy [5]. It finds larger retinal fractal dimension in his observation which are separately related with early stage diabetic retinopathy signs solemnly it is juvenile or Type-I diabetes [7]. Study presented in [8], fractal dimension features were measured from retinal fundus images of diabetic persons for estimation and association micro and macro vessel structure like diabetic retinopathy, neuropathy and nephropathy. Person who had lower fractal dimension has considered as he had proliferative diabetic retinopathy and neuropathy. Retinal Vessel calibration task is important task with marginal risk to predict the progression of proliferative diabetic retinopathy and same results for fractal dimension is observe in this study [9]. Automated detection system for retinal diseases requires segmentation of retinal vasculature as we know blood vessels and optic nerve head both are jointly present in eye furthermore; it was explained by ophthalmologist that changes in architectural distribution of eye vessels with respect to particular eye disease. In this section we plan a new technique for blood vessel separation in eye fundus images created on a FC-CRF model [10].

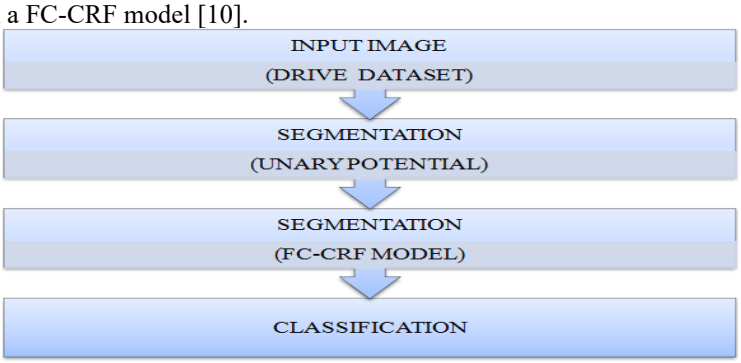


Fig 3: General Framework of Segmentation and Classification System

As we know potts model can't deal with thin and lengthened structure like retinal vessels. We conquer this complexity via a CRF model. Hence in this technique support vector machine is used for structured prediction by means parameters learned automatically by means of a structured output SVM. The system is trained in both the aspects with respect to publicly available STARE, DRIVE, HRF and CHASEDB1 datasets. Furthermore, we compare our technique with other techniques our results show better performance in terms of quality measures. It is observed that the fully connected model is capable of unique method work in dense potential than local neighbourhood based approach [11]. A result recommends that technique is appropriate for segmentation of elongated structures. Our detail technique is briefly explained in this section and general framework of system is shown in figure 3. In initial stage we describe local neighbourhood based and FC-CRF formulation. In next stage learning of models are performed by summarization using structured output Support Vector Machine. Then evolution task is done with respect to obtained features and finally classification is performed using SVM and K-NN classifiers.

IV.VESSEL SEGMENTATION USING CONDITIONAL RANDOM FILED

Conditional Random Fields approach is a statistical modelling technique, here mapping of pixels is done in graph form in CRFs model each pixels are considering as node and it is connected to other node which forms the edge with respect to connectivity rule, hence the segmentation task in this technique posed as an energy minimization problem to. Local neighbourhood based CRFs differs from FC-CRFs because in local neighbourhood based CRFs 4-pixel neighbourhood connectivity followed by each node [4] and in the FC-CRF every node is understood to be linked to each other pixel of the fundus image. Here y = {yi} a labelled pixels of the *I* image in label space *L* = {−1, 1}, where 1 is considered as retinal blood vessels and -1 extra class. Characterization of conditional random field (*I*, **y**) is done by Gibbs distribution:

$$p(Y|I) = \frac{1}{Z(I)} exp\left(-\sum_{c\in C_G} \varphi_C(Y_C|I)\right) \text{------ (a)}$$

Where Z(I) normalization constant, G is the graph of image I associated to I and C_G set of cliques, with potential ϕc [5]. Gibbs energy function can be derivative from following:

$$E(Y|I) = \sum_{C\in C_G} \varphi_{C(Y_c|I)} \text{ ------- (b)}$$

Energy minimization is performed for labelling that is the maximum some posteriori simply it is called MAP.

$$y^* = \arg\min_{Y\in L} E(Y|I) \text{ ------- (c)}$$

Minimization of *E(y|I),* results as binary segmentation of vessels. We use ψc(yc) to indicate Φc(yc|I). In addition, energy decomposition of unary and pairwise potentials are considered as higher order potentials [6]. Addition of unary potential and pairwise potential gives uses total energy.

$$E(Y) = \sum_i \psi_u\,(y_i\,, x_i) + \sum_{(i,j)\epsilon C_G} \psi_p\,\left(y_i\,, y_j, f_i, f_j\right) \text{------- (d)}$$

Here x_i is unary and f_i is pairwise features. Unary potentials describe labelling task on y, which are used for computation of a classifier. Similarly, pairwise potentials describe connections between pixels features with respect to their labels, according to set of cliques. Unary potentials are commonly obtained for local neighbourhood as well as FC-CRF as follows:

$$\psi_u\,(y_i, x_i\,) = -\langle w_{u_{y_i}}, x_i\rangle - w_{\beta_{y_i}}\beta \text{ ------- (e)}$$

β defined as bias, and w_{uyi} and $w_{\beta yi}$ associated with y_i labels are weighted vectors for features and the bias, xi is unary vector which arbitrary grouping of extracted features using retinal fundus image. Pairwise potentials are nothing but a linear grouping of functions. Hence, we obtained pairwise energy as follows:

$$\psi_p\left(y_i, y_j, f_i, f_j\right) = \mu\left(y_{i,}\, y_j\right)\sum_{m=1}^{M} w_p{}^{(m)}\, k^{(m)}\left(f_i^{(m)}\,, f_j^{(m)}\right) \text{ --------- (f)}$$

$k^{(m)}$ is defined as rigid function based on arbitrary feature, linear combination of weight is defined as $f^{(m)}$, $w_p{}^{(m)}$ and μ (yi, yj) defined the label compatible function. $f^{(m)}$ is traced similarity in between connected pixels determine by Gaussian kernels. It is obtained by connectivity rule applied on pixels' neighbours by using conditional random filed formulation. Compatible function is defined by μ, Parameters w_u, $w_p{}^{(m)}$ used to control the weight of the unary features as well as

pairwise kernels with respect to energy function additionally, and learning of bias is defined by w_β.

CRFs for Local Neighbourhood

LNB-CRFs are defined on above gridiron graphs. So, in this approach each pixel is understood to be linked via an edge to its 4-associated neighbours. The function is obtained with respect to pairwise potentials given as m^{th} pairwise feature as follows:

$$K^{(m)}\left(f_i^{(m)}, f_j^{(m)}\right) = \frac{\left|f_i^{(m)} - f_j^{(m)}\right|}{2^{\theta}_{(m)}} \text{ --------- (g)}$$

Wherever $\theta_{(m)}$ is a bandwidth that controls the weight of the dissimilarity of pixel features. The energy minimization of the grid approach is achieved by mincut/max-flow technique.

Fully Connected Conditional Random Filed Model

It is benefiting in segmentation process as it helps to improvise accuracy but it is this property is limited with respect to inference recently, research presented a competent inference approach by considering pairwise potential and taking mean filed approximation of CRF it helps to perform accurate segmentations in a fractions of minutes. Pairwise kernels for the FC-CRF are as follows:

$$k^{(m)}\left(f_i^{(m)}, f_j^{(m)}\right) = exp\left(-\frac{|p_i - p_j|^2}{2\theta_p^2} - \frac{\left|f_i^{(m)} - f_j^{(m)}\right|^2}{2\theta_m^2}\right) \text{------ (h)}$$

In this equation p_i and p_j are defined as co-ordinate vectors of pixels respectively. Kernel widths control the degree weight defined as θp and θ(m). For instance, when increase in lengthy interactions observed by θp and vice versa for local neighbourhoods. In the same way, when θ(m) increases tolerance is higher with respect to m^{th} feature and vice versa for lowering the tolerance successively.

V.CLASSIFICATION

In this section we explain classification techniques used in our automated system we use K-*NN* and SVM classifiers for classification we explain earlier for FC-CRF segmentation we used SVM properties as structured output SVM as we know we are dealing with thin and elongated retinal structures. Both classifiers explained in following.

K- Nearest Neighbour Classification Technique (K-NN)

It is a supervised classification method as name nearest neighbour it trains the nearest feature space it divides datasets into two sets testing and training each row contains k nearest training sets of pixels' resolution, classification is done using majority of votes working of K-NN is based on calculation of distances between training and testing data vectors calculation is done by Euclidian distance formulation as given below:

$$Euclidian\ distance = \sqrt{\sum_{i=1}^{N}(X_i - Y_i)^2} \text{ -------- (i)}$$

It took test illustration 'X' for decision making of k nearest neighbour in training phase and assigns 'X' into class which occurred with the k neighbours. As shown in (figure) below.

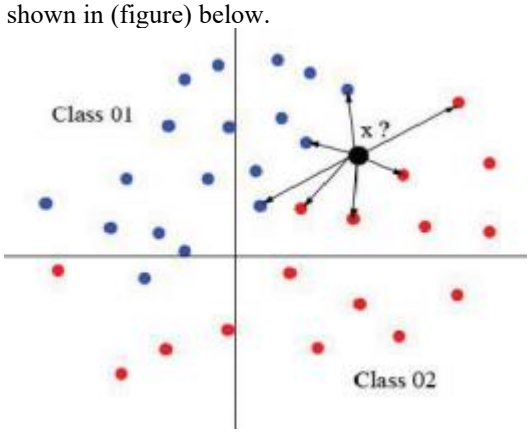


Fig 4: K-NN Classification

Support Vector Machine Classification Technique (SVM)

It is a supervised classification used in different machine learning approaches, working excellently for two group's classification it works on separating the hyperplane, it is superior when specified training labelled data is available hyperplane gives best output for the algorithm. It also works for two dimension features space it simply divide planes into two parts each class lay down in any side. In machine learning support vector machine is used for classification and regression analysis based on learning algorithm which perform data analysis it is supervised learning model, on the basis of training set SVM self-create a model for categorization by marking using hyperplane which points lay in which group developing non probabilistic binary linear classifier. An SVM is responsible for mapping of points and separating them with clear wide gap up to maximum extent. Latest examples are subsequently mapped into that same space and predicted which region of gap they fall. On other hand support vector machine competently carry out non-linear classification by tuning some parameters explain in below. Kernel is responsible for learning of hyperplane in linear classification; equation of linear kernel for prediction formulation is as follows:

$$f(X) = B(0) + sum\left(a_i * (X, X_i)\right) \text{ -------- (j)}$$

For every new input support vector is calculated by dot product with that input here X is input and X_i is support vector, coefficient B0 and a_i is estimated during training phase. Similarly, for kernel trick or polynomial kernel formulation is as follows:

$$K(X, X_i) = 1 + sum(X, X_i)\text{^}d \text{ --------- (k)}$$

Exponential defined as

$$K(X, X_i) = exp\left(-gamma * sum(X - X_i^2)\right) \text{ ---------- (l)}$$

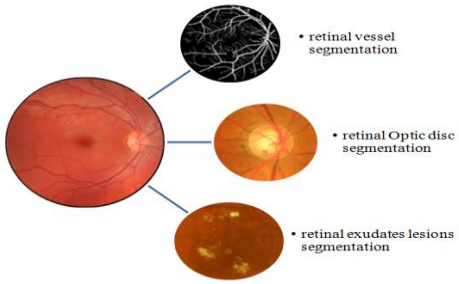


Fig 5: Framework of Hybrid Segmentation System

The Regularization parameter is responsible for optimization of support vector machine it acknowledges how much misclassification should be avoided. Optimizer chooses smaller hyperplane for huge C values if hyperplane doing correct classification of training points on the other hand, a minute value of C forces optimizer though hyperplane misclassifies more points for a larger-margin separating hyperplane. The gamma parameter is responsible for defining how influence of a particular training instance reaches, with low and high values respectively low means far and high means near. Hence it means that, during separation by hyperplane is perform low gamma points are far away from hyperplane vice versa for high gamma with respect calculation of separation. A margin is nothing but a separation of line to the nearby class points. We consider good margin as if separation is larger for both classes. Good margin means points lay in relevant class as a no crossing to further class.

VI. METHODS

In this section we explain the technique and its working policy; as discussed in previous section we know that we developed a hybrid multi-anatomical segmentation system which can extract features in a single instance to work better we provide fuzzy logic and mathematical morphological characteristics for getting fast and accurate performance. The universal hybrid framework for soft thresholding is shown in fig 5. This projected system consists of three subsystems which work with respect to characteristics of mathematical morphology and fuzzy set logic. Simple techniques used for image segmentation tasks, in general and for biomedical image segmentation tasks particularly. Usually, thresholding technique work to find global value for maximization of the partition among different classes in the fundus image, this is useful technique for distinct areas when we had minimum interference in the region of grey level clusters, as we know organs and tissues in medical imaging system are undistinguishable, for that reason, thresholding segmentation methods are used broadly for diverse grey levels, thresholding implement pixel wise approach that means same intensity pixels

are segmented in specified objects through a particular hard value. When soft transaction occurs between pixels or uneven illumination is present in pixels to overcome this problem by using region-wise thresholding techniques. In our system adaptive local fuzzy thresholding is considered as hard segmentation and mathematical morphological operations is soft segmentation. General flow chart of our system is shown in the fig 6.

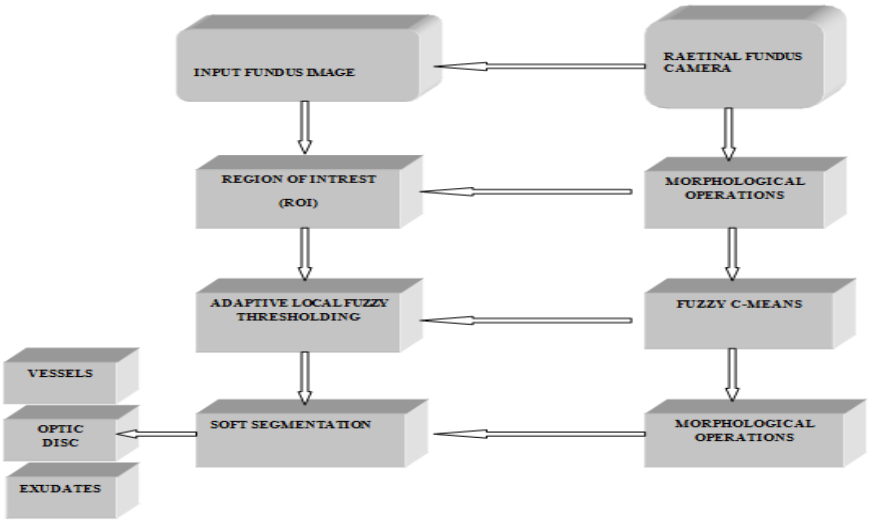


Fig 6: Flow Chart of Our System

Morphological operators are responsible for the pre- processing and post-processing stage of the system, where adaptive local fuzzy thresholding is responsible for processing stage, as mentioned in flowchart, our system involves region of interest with respect to all vessels, optic disc and exudates and then it follows coarse as well as soft segmentation .In the first stage to obtain ROI we consider target retina is Iretina from this we extract enhanced IROI with respect to retinal vessels, optic disc and exudates simultaneously by lowering computational cost after that morphological operators performs pre-processing such as identification of target. Then we use IROI as input for local adaptive fuzzy thresholding, which produce IROI images of hard-segmentation, finally we apply mathematical morphological operations on IROI in the soft segmentation step which follows binarization and convex-hull transformation for smoothing of images those obtained finally we can give them notations like for vessel it is Ivessel for optic disc it is IOptic Disc and for exudates it is Iexudates.

VII.CONCLUSION

The retinal vessel segmentation and detection of glaucoma using fully connected random filed model is presented in this thesis the purpose of segmentation mainly for detection and classification of glaucoma from eye fundus images, feature extraction and retinal vasculature reconstruction is more effectively obtain by using fully connected random filed model then unary potential or a local neighbourhood based conditional random filed. The efficiency is measured in terms of sensitivity, specificity and accuracy, sensitivity is defined as accurate identification of disease or true positive rate and specificity is accurate identification of no disease or true negative rate. Finally, accuracy is defined as correctly identification of instances. Classification results shows K-NN is more effective for fully connected conditional random filed model then SVM, our retinal vessel segmentation results on DRIVE, STARE, CHASEDB1 and HRF shows expressive performance on dense potentials. Further they can be used for numerous biomedical and biological applications for identification and detection of various problems. Furthermore, we observe in some cases unless and until retinal vessels shows healthy symptoms with respect to our FC-CRF segmentation and classification system but ophthalmologist marked as unhealthy due to changes in optic disc or presence of lesions in exudates island. To overcome this problem, we further go for retinal multi-anatomical structure segmentation including optic disc, exudates and vessels by unsupervised technique. We used mathematical morphological operations and hybrid fuzzy set theory to develop more powerful standalone hybrid segmentation system which contains three segmentation subsystems for anatomical structures. The research approach makes two most important aid, first, our proposed system provides single hybrid system that perform segmentation task on multi-anatomical structures hence no need to develop separate identification and detection system and second, our system is extremely robust and accurate and we validate our results using freely available datasets like DRIVE, STARE, CHASEDB1, HRF, DRITSHTIGS, and DiaRetDB1 retinal datasets. Additionally, its performance is better for extraction of retinal vessels and optic disc even if fundus images having pathologies. Hence, it can be considered perfect for diagnosis of medical applications. Experimental results and

performance showed that our proposed hybrid system gives us superior results with respect to specificity, sensitivity and accuracy.

REFERENCES

[1]. World Health Organization et al. URL:http://www.who.int

[2]. George R., Ve R. S. and Vijaya L. (2010) "Glaucoma in India: Estimated burden of disease", *Journal of Glaucoma, Vol. 19, Issue* 6, pp-391–397.

[3]. Etienne C. F. (2015) "Reducing avoidable blindness and visual impairment in the Region of the Americas", *Revista Panamericana de Salud Pública, Vol. 37, Issue* 1, pp-1–3.

[4]. Prokofyeva E. and Zrenner E. (2012) "Epidemiology of major eye diseases leading to blindness in Europe: A literature review", *Ophthalmic Research, Vol. 47, Issue* 4, ppp-171–188.

[5]. Leasher, J. L., Bourne, R. R. A., Flaxman, S. R., Jonas, J. B., Keeffe, J., Naidoo, K., Pesudovs, K., Price, H., White, R. A., Wong, T. Y., Resnikoff, S., & Taylor, H. R. (2016). "Global estimates on the number of people blind or visually impaired by diabetic retinopathy: A meta-analysis from 1990–2010" *Diabetes Care, Vol. 39, Issue* 9, pp-1643–1649.

[6]. Tham Y. C., Li X., Wong T. Y., Quigley H. A., Aung T. & Cheng C. Y. (2014) "Global prevalence of glaucoma and projections of glaucoma burden through 2040: A systematic review and meta-analysis" *Ophthalmology, Vol. 121, Issue* 11, pp-2081–2090.

[7]. Abràmoff M. D., Garvin M. K. and Sonka M. (2010) "Retinal imaging and image analysis", *IEEE Reviews in Biomedical Engineering, Vol. 3*, pp-169–208.

[8]. Abràmoff M. D. & Niemeijer, M. (2015) "Mass screening of diabetic retinopathy using automated methods", G. Michelson (Ed.), *Teleophthalmology in preventive medicine,* pp-41–50.

[9]. Fraz M. M., Remagnino P., Hoppe A., Uyyanonvara B., Rudnicka A. R., Owen C. G. and Barman, S. A. (2012) "An ensemble classification-based approach applied to retinal blood vessel segmentation", *IEEE Transactions on Biomedical Engineering, Vol. 59, Issue* 9, pp-2538–2548.

[10]. Haleem M. S., Han L., van Hemert, J. and Li B. (2013) "Automatic extraction of retinal features from colour retinal images for glaucoma diagnosis: A review" *Computerized Medical Imaging and Graphics, Vol. 37, Issue:* 7–8, pp-581–596.

[11]. LeCun Y., Bengio Y. and Hinton G. (2015) "Deep learning", *Nature, Vo. 521, Issue:* 7553, pp-436–444.

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