Ensemble System for Optic Disc and Macula Detection

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Abstract— **Diabetic retinopathy (DR) is an eye disease that is associated with persons who are having diabetes more than five years. It is a major cause of poor vision. To improve the accuracy of the classification results, Pre-processing has been carried out. In this stage, some of the non-lesion regions such as optic disc (OD), and macula has to be detected and removed to improve the accuracy of abnormal lesions detection. No single algorithm has detected these regions exactly. An ensemble system is proposed to detect OD and macula in retinal fundus images. It is experimented using publicly available DIARETDB1 database. The proposed algorithm shows better performance than existing algorithms.**

Index Terms— **Diabetic Retinopathy, Macula Detection, Optic Disc Detection, Pre-Processing**

I. Introduction

Medical imaging is a very popular research area in these days. It includes computer aided diagnosis of different diseases by taking digital images as input. Computer assisted diagnosis for various diseases is very common now a days and medical imaging is playing a vital role in such computer assisted diagnosis. Retinal images are used for the screening and diagnosis of diabetic retinopathy, an eye disease. An automated system for the diagnosis of diabetic retinopathy should highlight all signs of disease present in the image. In order to improve the accuracy of the system, the retinal image quality must be improved by removing non-lesion regions such as optic disc and macula.

There are various existing algorithms in the literature to detect the non-lesion regions. There is no guarantee that the single algorithm gives better performance. This paper has proposed an ensemble system to detect the optic disc and macula in retinal fundus images. Four algorithms are used for detecting optic disc and macula separately. The outputs of these four algorithms are combined to produce the hotspot region using circular template voting scheme.

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II. Previous Research

Hung-Kuei Hsiao et al [1] have proposed a novel illumination correction operation to localise the optic disc. Supervised gradient vector flow snake (SGVF snake) model is proposed for optic disc segmentation in this paper. The main drawback of conventional GVF snake is insufficient to segment contour due to vessel occlusion and fuzzy disc boundaries. Due to this reason, the SGVF snake is extended in each time of deformation iteration. Contour points can be classified and updated according to their corresponding feature information. Classification relies on the feature vector extraction and the statistical information generated from training images. The proposed algorithm is experimented with two publicly available databases, Digital Retinal Images for Vessel Extraction (DRIVE) database and Structured Analysis of the Retina (STARE) database, of color retinal images. The experimental results show that the overall performance is with 95% correct optic disc localization from the two databases and 91% disc boundaries are correctly segmented by the SGVF snake algorithm.

Daniel Welfer, Jacob Scharcanski, Diane Ruschel Marinho [2] have proposed a new adaptive morphological method for the automatic detection of the optic disk in digital color eye fundus images. This approach has been used to identify the optic disk center and the optic disk rim. This is experimented with the DRIVE and DIARETDB1 databases. The proposed method is able to detect the optic disk center with 100% and 97.75% of accuracy, respectively. Using the proposed method, the rim of the optic disk is detected in all images of the DRIVE database with average sensitivity and specificity of 83.54% and 99.81%, respectively, and on the DIARETDB1 database with average sensitivity and specificity of 92.51% and 99.76%, respectively.

Meindert Niemeijer et al [3] presented a fully automated, fast method to detect the fovea and the optic disc in digital color photographs of the retina. This paper has utilised a kNN regressor to predict the distance in pixels in the image to the object of interest at any given location in the image based on a set of features measured at that location. The point with the lowest predicted distance to the optic disc is selected as the optic disc center. An extensive evaluation is performed on 500 images from a diabetic retinopathy screening program and 100 specially selected images containing gross abnormalities. The proposed method found the optic disc in 99.4% of regular screening images and 93.0 % for the images with abnormalities.

An improved gradient vector flow (GVF) based algorithm [4] has been proposed to successfully segment the optic disc in retinal images. Existing algorithms lead to less accurate segmentation results in certain cases due to the compromise of internal and external energy forces within the resulting partial differential equations. In this paper, a new mean shift-based GVF segmentation algorithm that drives the internal/external energies is presented. The proposed method incorporates a mean shift operation within the standard GVF cost function to arrive at a more accurate segmentation. Experimental results demonstrate that the presented method optimally detects the border of the optic disc.

A new approach called Topological Active Nets [5] has been proposed to locate the optic disc in digital retinal fundus images. This is a deformable model used for image segmentation that integrates features of region-based and edge-based segmentation techniques. It is being able to fit the edges of the objects and model their inner topology. In this paper the active nets incorporate new energy terms for the optic disc localisation. Optimisation is performed using a genetic algorithm, with new ad hoc genetic operators.

Daniel Welfer et al [6] have proposed a new adaptive mathematical morphological approach for the automatic segmentation of the optic disk in digital color fundus images. The proposed method is robust under varying illumination and image acquisition conditions. Experimental results based on two publicly available eye fundus image databases can achieve a better performance than other known methods proposed in the literature. Using the DRIVE database (which consists of 40 retinal images), the proposed method achieves a success rate of 100% in the correct location of the optic disk, with 41.47% of mean overlap. In the DIARETDB1 database (which consists of 89 retinal images), the optic disk is correctly located in 97.75% of the images, with a mean overlap of 43.65%.

A geometrical parametric model [7] has been proposed to identify the position of the optic disc (OD) in retinal fundus images. This method is based on the preliminary detection of the main retinal vessels. All retinal vessels originate from the OD and their path follows a similar directional pattern (parabolic course) in all images. Using samples of vessel centerline points and corresponding vessel directions, provided by any vessel identification procedure, model parameters are identified by means of a simulated annealing optimization technique. These estimated values provide the coordinates of the center of OD. Experimental evaluation is performed using the set of 81 images from the STARE project, containing images from both normal and pathological subjects. Accuracy achieved in detecting the OD position is 98% even in difficult pathological situations.

Sandra Morales et al [8] have proposed a method based on mathematical morphology and principal component analysis (PCA) for the extraction of the optic disc contour. The proposed method makes use of different operations such as generalized distance function (GDF), a variant of the watershed transformation, the stochastic watershed, and geodesic transformations. The output of PCA is given as input to the segmentation method. The purpose of using PCA is to achieve the gray-scale image that better represents the original RGB image. The proposed algorithm has been validated on five public databases to achieve good results. The average values obtained (a Jaccard's and Dice's coefficients of 0.8200 and 0.8932, respectively, an accuracy of 0.9947, and a true positive and false positive fractions of 0.9275 and 0.0036) demonstrate that this method is robust for the automatic segmentation of the optic disc.

An automated system [9] is presented to find the location of the major anatomical structures such as optic disc, macula, and vessels in color fundus photographs. These structures are found by fitting a single point-distribution-model to the image that contains points on each structure. The proposed method can handle optic disc and macula centered images of both the left and the right eye. It uses a cost function, which is based on a combination of both global and local cues, to find the correct position of the model points. The global terms in the cost function are based on the orientation and width of the vascular pattern in the image. The local term is derived from the image structure around the points of the model. To optimize the fit of the point-distribution-model to an image, a sophisticated combination of optimization processes is proposed which combines optimization in the parameter space of the model and in the image space, where points are moved directly. Experimental results are presented demonstrating that the specific choice for the cost function components and optimization scheme are needed to obtain good results.

Rashid Jalal Qureshi et al [10] proposed an efficient combination of algorithms for the automated localization of the optic disc and macula in retinal fundus images. Single algorithm may or may not be optimal. An ensemble of algorithms is used to obtain an improved optic disc and macula detector by combining the prediction of multiple algorithms, benefiting from their strength and compensating their weaknesses. Optic disc or macula center is the location with maximum number of detectors' outputs. The performance of integrated system is compared with the detectors working separately. The proposed combination of detectors has achieved overall highest performance in detecting optic disc and fovea closest to the manually center chosen by the retinal specialist.

Daniel Welfer, Jacob Scharcanski, Diane Ruschel Marinho [11] presented a new fovea center detection method based on known anatomical constraints on the relative locations of retina structures, and mathematical morphology. The proposed method is robust to local disturbances introduced by pathologies in digital color eye fundus images. It is experimented using the DRIVE image database and the DIARETDB1 database. It achieves a success rate of 100% and 92.13 % to detect the fovea center using DRIVE image database and the DIARETDB1 database. These results indicate that the proposed approach can achieve a better performance than existing methods.

M.H. Ahmad Fadzil, Lila Iznita Izhar, Hanung Adi Nugroho [12] has developed a semi-automated approach for determination of Fovea Avascular Zone (FAZ) using color images. The enlargement of FAZ area enables physicians to monitor progression of the DR, A binary map of retinal blood vessels is artificially generated from the digital fundus image. All the vessel ends forming FAZ are used for analysis. The proposed method has achieved accuracies from 66.67% to 98.69% compared to accuracies of 18.13–95.07% obtained by the manual segmentation of FAZ regions.

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III. PROPOSED ALGORITHM

An ensemble of classifiers is more accurate than the individual classifiers. It is a set of classifiers whose individual decisions are combined on the basis of some criterion to classify new inputs. A collection of optic disc and macula detector algorithms are combined into a single system for finding a more accurate optic disc and macula center.

A. Algorithms used for OD Detection

M. Foracchia et al [7] proposed a method based on a model of the geometrical directional pattern of the retinal vascular system. The proposed method is based on the detection of the area of convergence of vessels and also the fitting of a model with respect to the entire vascular structure. Here the OD position is considered as the point of convergence of all vessels. A common vascular pattern is present among all the retinal images. Main vessels originate from the OD and follow a similar directional pattern (parabolas). A geometrical parametric model is proposed to determine the direction of retinal vessels at any position in the image. Two model parameters identified are the coordinates of the OD center. This can be achieved using the vessel centreline points and vessel directions obtained from the vessel extraction procedure. The optimal model parameters are identified using a simulated annealing optimization technique. The performance of the proposed method is dependent on the availability of a good portion of the vascular structure in the image. The result of the vessel extraction procedure also affects the correct positioning of the OD. The choice for the identification of model parameters is also dependent on the accuracy of OD detection. Model Parameters should be selected in such a way that it should minimize the weighted residual sum of squares (RSS). However these are not critical issues to achieve good results. The accuracy achieved by the algorithm is 98% even in difficult pathological situations.

Daniel Welfer et al [6] proposed an adaptive method based on a model of the vascular structure for the automatic segmentation of the optic disk in digital color fundus images. It consists of two stages: (1) optic disk localisation; (2) optic disk boundary detection. The proposed method locates the optic disk with the help of origin of main vessels. First, an internal point to the optic disk is identified. The intercept of the horizontal line and the main vessels arcade fragment of the image provides this optic disk internal point. Next, several other points in the vicinity of this internal point is detected based on the vascular tree. The optic disk boundary is detected by a region growing method, using seeds as the pixels connected to the internal point of the disk. Using the watershed transform from markers with the internal and external markers as parameters, several optic disk boundary shapes are obtained. Each one is centered at one internal marker. Among the k boundary shapes, select the one with the highest compactness and largest area as an estimate of the optic disk boundary shape. To refine the estimate of the optic disk boundary, a new internal and external markers are obtained. Morphological operation is applied on the selected boundary shape and used as a new internal marker. A circle centered in the previous internal marker is used as external marker. The radius of this circle must be larger than the optic disk radius to ensure that the entire optical disk is within the circle. Using the watershed transform from markers with these new two markers, a refined optic disk boundary estimate is obtained. The proposed method achieves a success rate of 100% and 97.75% in the DRIVE and DIARETDB1 databases respectively.

Daniel Welfer et al [2] introduced an automatic method for detecting the optic disk in digital color eye fundus images. This approach is based on mathematical morphology techniques. This method has been designed to detect the optic disk center and the optic disk rim. This consists of two stages: (a) coarse detection of the optic disk rim; and (b) fine detection of the optic disk rim. This approach has not used any pre-defined shape and not influenced by the outgoing vessels crossing the optic disk. The optic disk rim detection is more effective if the input image background is more evenly illuminated. The proposed method is evaluated on publicly available datasets such as DRIVE and DIARETDB1. The optic disk center is detected with an accuracy of 100% and 97.75% on DRIVE and DIARETDB1 databases respectively. The rim of the optic disk is detected in all images of the DRIVE database with average sensitivity and specificity of 83.54% and 99.81%, respectively. With the use of DIARETDB1 database, the average sensitivity and specificity of 92.51% and 99.76% are achieved using the proposed method.

A new approach [8] has been proposed for the automatic detection of the optic disc contour. It does not require any intervention by clinicians. It is mainly based on techniques such as mathematical morphology and principal component analysis (PCA). To locate the OD, the first step is to obtain the grayscale image from the original RGB image. This can be achieved using PCA which combines the most significant information of the three RGB components. The next step is to locate OD with the help of operations based on mathematical morphology. Various operations such as generalized distance function (GDF), a variant of the watershed transformation, the stochastic watershed, and geodesic transformations are used in this approach. Experimental evaluation has been conducted on five different public databases. Results are obtained with an average accuracy of 0.9947, and a true positive and false positive fractions of 0.9275 and 0.0036. Promising results are achieved on databases with a large degree of variability.

B. Algorithms used for Macula Detection

Meindert Niemeijer et al [9] presented an automatic system which finds all the normal retinal anatomy such as optic disc, macula, and vessels in one operation by fitting a single point-distribution-model to the image. By fitting the model, the location of a set of 16 model points is found within the image. As each of the model points is defined to lie on a certain anatomical structure, the location of the structures is obtained. The proposed method can handle optic disc and macula centered images of both the left and the right eye. To find the correct position of the model points, the cost function which combines both global and local terms is used. The

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global terms are based on the orientation and width of the vascular pattern in the image. The local term is derived from the image structure around the points of the model. A combination of optimization mechanisms is used to optimize the parameters in the model and in the image space to achieve a fit of the point-distribution-model to an image. In the screening set, the proposed system is able to find the vascular arch in 93.2%, the macula in 94.4%, and the optic disc location in 98.4%. For the test set, the success rate achieved is 77.0%, 92.0%, 94.0%, and 100% respectively.

M.H. Ahmad Fadzil et al [12] developed a semi- automated image processing algorithm for area analysis of Fovea Avascular Zone (FAZ) using digital fundus images in a non-invasive manner. FAZ is determined based on the selection of vessel and pathology end points near or at the perifoveal capillary network. A binary map of retinal blood vessels is computer generated from the digital fundus image to determine vessel ends and pathologies surrounding FAZ for area analysis. The accuracy of FAZ area is affected by the segmentation of the retinal blood vessels. . The analysis of FAZ has been used to grade the severity of DR. The accuracy achieved has a range from 66.67% to 98.69% compared to accuracies of 18.13–95.07% obtained by manual segmentation of FAZ regions. The proposed method has improved the mean accuracy of FAZ determination by 13.1% and reduced the standard deviation by a factor of 1.1.

Daniel Welfer et al [11] presented a new method to detect fovea automatically in color retinal images based on the spatial relationship between the optic disk diameter and the fovea region. Region of Interest (ROI) is selected using this spatial relationship. Bright lesions and dark lesions are removed before finding fovea candidate regions. The proposed method tends to be more robust to image artifacts near the fovea region, such as exudates, microaneurysms and microhemorrhages. Fovea candidate regions are detected inside ROI by using specific morphological filters. The center of the darkest candidate region, located below the optic disk center, is selected as the fovea center. Experimental results indicate that the proposed approach achieves a fovea detection rate of 100% and 92.13% for the DRIVE database and DIARETDB1 database respectively.

A fully automated system [3] has been developed for the detection of the location of the optic disc and the fovea using kNN regressor. The proposed method makes few assumptions about the way in which the retinal image has been acquired (i.e. optic disc centered or fovea centered). It integrates cues from both the local vasculature and the local image intensities. It uses a kNN regressor and a circular template to estimate the distance to a certain location in a retinal image (i.e. the optic disc and the fovea). It first finds the optic disc and then searches for the fovea based on the optic disc location. By finding the position in the image where the estimated distance is smallest, both the optic disc and fovea can be detected. The point with the lowest predicted distance to the optic disc and to the fovea within the foveal search area is selected as the optic disc center and fovea location respectively. The proposed system found the optic disc and the fovea in 99.4% and 96.8% out of 500 cases, respectively. For the images with abnormalities, these numbers were 93.0% and 89.0% respectively.

C. Proposed combination of the algorithms

An ensemble classifier can be more accurate than any of its individual members in the proposed system. If some of the algorithms gives an erroneous results, then the remaining algorithms can correct this error. Experimental results have shown that combining the predictions of multiple detectors is more accurate than any of the individual detectors in the ensemble system.

D. Shift factor Computation

To compute the distortion in the data, macula or OD centers detected by all the algorithms are compared and mapped onto single image. The response of each algorithm may or may not be slightly deviated from the manually selected macula or OD centres. A shift operation is applied to compute the distortion effects in the distribution. It is used to make the individual algorithms unbiased in the ensemble system. The shift factor can be calculated as the average difference between the candidate of the algorithm and the manually selected center. The combined output of all the algorithms is generated by applying the distortion shift factor on each output pixel coordinate.

E. Majority Voting for Hotspot region identification

A circular template voting scheme is used to determine the hotspot region, i.e., an area in the image where majority of the outputs lies. A circular template of radius R is fit on each pixel in the image and outputs of candidate algorithms that fall within the radius of the predefined circular template are counted. The circular template covering the maximum number of optic disc detector outputs in its radius is considered to be a hotspot. There can be more hotspots covering the maximum number of detector outputs in their radius; hence they together define a hotspot region, the patch with highest probability. The radius R of the template was set to 102 pixels, keeping in view the fact that clinically this is the average OD radius at the investigated resolution. The outputs of the four algorithms are combined for OD and macula detection. Using the majority voting scheme, the center of the circular templates covering the maximum number of OD detectors and macula detector outputs in its radius is considered to be the OD and macula hotspots, respectively.

IV. RESULTS AND DISCUSSION

The methods have been evaluated on the basis of two criterions, i.e., to fall inside the manually selected optic disc patches, and to be close to the manually selected OD center. To localize macula and detect fovea, the methods have been evaluated on the basis of two criterions, i.e., macula error and fovea error. The macula error is the number of times the algorithm's output falls within the 0.5 DD radius of the manually selected macula center and fovea error, i.e., the

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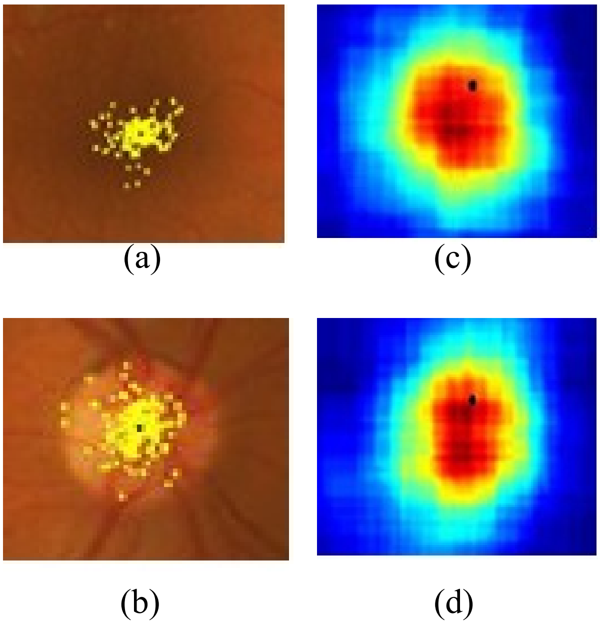

Figure 1. (a) and (b) are original images, (c) and (d) OD segmented image

average Euclidean distance of these candidates and the manually selected centers.

V. CONCLUSION

A new framework is developed for combining state-of-the-art OD/ fovea in terms of improving performance as compared to individual algorithms. The proposed combination outperformed all the individual algorithms. A majority voting and weighted linear combination based scheme that count the number of outputs of the algorithms falling in a specified radius circle is marked as a hotspot. The proposed method achieved highest performance, and closest to the manually selected optic disc center chosen by a retinal specialist. Fig.1 shows the results of the proposed algorithm.

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