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3D Reconstruction of Retinal Images using Fundus Image for Increased Anatomic View and Glaucoma Detection

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Abstract: ***For diagnosing eye diseases the structure analysis of structure Optic Nerve Head (ONH) and registration of retinal images are very important. So this paper proposed the 3D construction and registration of retinal images. The previous reconstruction method states disparity map estimation as a depth cue to remove uncertainty of the relative positions and then by using guided filter final depth map can be obtained. The red cyan anaglyph can be computed by using this depth map and 3D structure of ONH can be constructed. After reconstruction we are going to find glaucoma detection. Early diagnosis and optimal treatment have been shown to minimize the risk of visual loss due to glaucoma. The glaucoma detection phase of work consist of feature extraction followed by calculation of performance parameters.***
Keywords: 3D reconstruction, Optic-nerve head (ONH), Disparity map, image registration, SVM.

I. INTRODUCTION

The fundus shape can be reconstructed from the stereo pair images, in principle, by identify the virtual quadratic surface produced by eye-lens first, then, back-projecting the quadratic surface onto spherical surface of fundus. But, in this process, we need two steps of optimizations, one for reconstruction of the quadratic surface, and the other for the final 3D fundus pattern, because the read-outs of the image point coordinates have image noise. It is uncertain that these two steps of the optimization result in total and stable optimization. Here we propose a practical algorithm to identify the above mentioned parameters and, at the same time, obtain the 3D fundus pattern. A point on one of the stereo images corresponds to a line-of-sight in the space in front of the camera. By following the lines-of-sight of the stereo fundus image points, we recover those parameters with an iterative optimization. All the pairs of lines-of-sight of corresponding point pairs of the stereo fundus images, after refracting at the modeled single lens, encounter each other on the sphere of the fundus. Using this fact, we optimize the parameters so that all the pairs of the crossing points of the pair of the lines-of-sight on the sphere become nearest.

The quantitative assessment of retinal vasculature provides useful clinical information to assisting the diagnosis of various diseases. The detection and measurement of retinal vasculature can be used to quantify the severity of disease and the progression of therapy. Retinal blood vessel tree geometry, topology and vessel tracking have been studied by means of digital image processing mainly using retinal images which are also known as fundus images [1, 2]. However, the majority of these works have been carried out in 2D fundus images (Fig. 1(a) and 1(c)).

A first effort to obtain a 3D view of fundus images was developed by [3, 4]. Their work focuses on the reconstruction and display of 3D fundus patterns using branching vessel point correspondences between images of two and multiple views. Another approach to reconstruct the retinal fundus is presented by [5] where an epipolar geometry with a plane-and-parallax method is used. An approach to actually reconstruct the skeleton of a blood vessel tree is presented by [6] where a self-calibration based on essential matrix is used. We have presented before a previous work with a first approximation to the 3D reconstruction of blood vessel tree surfaces [7], some improvements will be presented and discussed herein. Photogrammetric analysis of features in images of human ocular fundus is affected by various sources of error, like aberrations of the fundus camera and the eye optics. The magnification in a fundus image is equal to the focal length of the fundus camera divided by the focal length of the eye. This formula can only be applied under different ametropic conditions and changes in the camera position with respect to the subject eye. This difference in magnification between one fundus image and another from different subjects has been pointed out in [8]. As a result, it is not possible to make a direct comparison between measurements from different subjects. Consequently, the 3D metric reconstruction of retinal blood vessel trees is a great challenge.

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II. RELATED WORK

S.T. Barnard et al [6], have given a method which involves the estimation of depth differences or 3D shape using two retinal images of the same scene under slightly different geometry. By measuring the relative position differences or disparity of one or more corresponding patches or regions in the two images, the 3D shape can be estimated using the underlying structure information.

F. Guo et al [7], have given method for retinal image registration, the commonly used registration method for retinal images is feature-based method. The technique can be classified into region- and point-matching categories. The region-matching approaches consider all the features in a region as a whole and identify the transformation parameters by minimizing the similarity measures. Point-matching methods rely on the matched features in both images, and the technique mainly consists of two steps: feature matching and transformation estimation. In this paper, a novel point-matching method is proposed to mosaic retinal image pairs.

Kevin Noronha et al [8] have given work that specifies the methods used to detect main features of retinal fundus images such as optic disk, fovea, and exudates and blood vessels using different techniques. To determine the optic Disk and its center Author find the brightest part of the fundus and apply Hough transform. Sangyeol Lee et al [9] presented the validation tool for any retinal image registration method by tracing back the distortion path and accessing the geometric misalignment from the coordinate system of reference standard. S. Sekhar [10] performed a work of automated localization of retinal optic disk using hough transform. The retinal fundus image is widely used in the diagnosis and treatment of various eye diseases such as diabetic retinopathy and glaucoma. The proposed methodology consists of two steps: in the first step, region of interest (ROI) is found by image by means of morphological processing, and in the second step, optic disk is detected using the Hough transform.

Zhuo Zhang et al [11], presented an online dataset, ORIGA-light, which aims to share clinical retinal images with the public. Author had updated the system continuously with more clinical ground-truth images. The method focuses on optic disk and cup segmentation. Vahabi Z et al [12] described a filtering approach like Sobel edge detection, Texture Analysis, Intensity and Template matching to detect Optic Disc. The algorithm is applied in wavelet domain on 150 images of dataset.

Choe et al [14] have proposed a method which is a computer vision based approach that extracts the location of vessels bifurcation. For extracting vessel bifurcation plane and parallax method is used. Then estimates the fundamental matrix for nearly planar surface, the retinal fundus. The use of mutual information is used for the estimation of the dense disparity maps, where the matched Y-features are used for estimating the bounds of the range space disparity. Y-feature is the most commonly used feature since it is easy to detect and well distributed in fluorescein images. The method consists of three steps: First, accurate positions of bifurcation of vessels are extracted and matched across images using an articulated Y-feature model. Second, using the matched Y-features, a plane-and-parallax approach is considered for estimating the epipolar geometry, and the search space on the scan line for stereo matching is estimated. Subsequently, a dense disparity map is estimated by matching point using a mutual information method. The 3-D shape of lesions, a fovea, and an optic disc are also accurately estimated.

Koicchiro et al [15] proposed a method to display 3D fundus from a set of multiple partial images of fundus. The different views are obtained by shifting the fundus camera. This method used the concept that the fundus has a spherical shape and the image of eye lens results in a quadratic surface. This method calculates all the optical parameters. A combination of eye lens and the enlarging contact lens are modelled and identified the optical parameters of modelled lens. Then the spherical surface of the fundus is mapped on to a quadratic surface as its real image. Then extracts the feature points from fundus image and find correspondences and the corresponding pairs are registered on a quadratic surface. Parallely the viewing direction of camera to take individual images is identified to produce best corresponding pairs. The fundus pattern are back projected from the multiple images to the reconstructed sphere.

III. PROPOSED WORK

The proposed work is as shown in block diagram in figure 1.

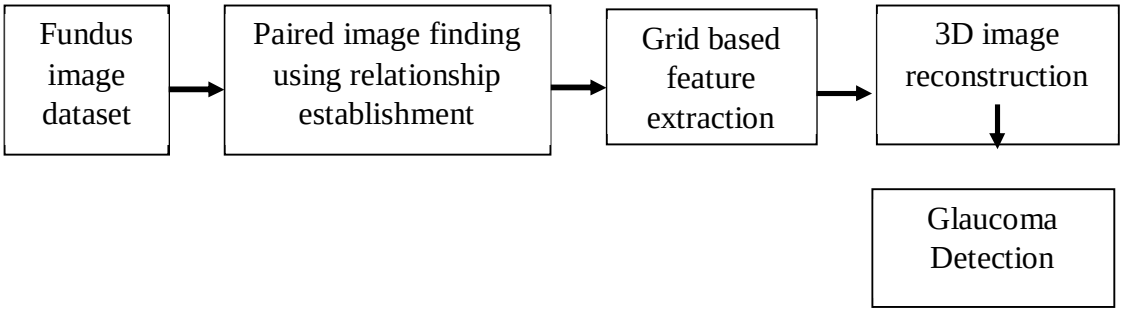

Figure1: block diagram of proposed work

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A. Dataset

The fundus image dataset can be used from freely available datasets such as STARE, DRIVE.

B. Relationship Establishment

The aim of the stage is to establish the vasculature relationship between image pair because blood vessels are robust towards geometrical transformation and intensity changes. Whether the blood vessels can be successfully segmented determines the quality of feature points' extraction.

The guided filter [9] will be first used to enhance the original input images since the blood vessels in the enhanced retinal images are more obvious than those in the original images, which make it much easier for identifying the feature and structure of the vessels. Then, Jerman's 2D Hessian based vessel enhancement filter [11] will be adopted here since the filter is proved to be quite effective for enhancing the retinal vasculature. The output of the Hessian-based filter is the vessel probability map of the enhanced retinal image.

C. GMS Features Extraction

The aim of the stage is to divide the vessel segmentation image into 4 different quadrants and apply a GMS feature correspondence technique to each region. The GMS method is based on the key observations that a true match may have many more supporting matches in its surrounding area than a false match, and the matching results seem quite promising for most natural scene images and robust than conventional feature descriptors (e.g. SIFT, SURF, etc.).

However, from the point of view of the whole retinal images, GMS method always fails in extracting the feature points in some local regions with lower contrast and less vessels, which will cause an incorrect transformation estimation in the following steps. Therefore, the ISNT prior that widely accepted in ophthalmology field is used here to divide the vessel segmentation image into different quadrants. According to the ISNT rule [12], the neuro retinal rim can be divided into four quadrants: inferior (I), superior (S), nasal (N) and temporal (T).

D. 3D Reconstruction

The aim of the stage is to identify the transformation parameters and mosaic the input retinal images. The GMS feature points from the four quadrants are all used to find the homography, which is a 3 by 3 matrix and contains the scale, rotation, and translation information of the two input images.

Since the feature correspondence across two images may not be unique due to the similar angle values, the RANSAC algorithm [13] are also adopted here to eliminate false matching from the corresponding GMS points. Thus, by applying the homography to one of the input retinal images, a transformed image can be obtained to align the mosaic image.

Perform required transformation in terms of horizontal and vertical shifts, scaling and rotations.

Calculate scaling by formula $\sqrt[2]{\frac{(x1-x2)^2+(y1-y2)^2}{(x3-x4)^2+(y3-y4)^2}}$

Theta= $\sqrt[2]{\frac{tan^{-1}(x1-x2)^2+(y1-y2)^2}{tan^{-1}(x3-x4)^2+(y3-y4)^2}}$

Where x1, x2, y1 and y2 are locations of first image and x3,x4,y3 and y4 are locations of second image. Shift x=x3-x1 and Shift y= y3-y1

E. Glaucoma Detection

The glaucoma detection phase of work consist of feature extraction and classification using support factor classifier.

F. Feature Extraction

The input 3D constructed image features is extracted using Otsu threshold based blood vessel segmentation. The segmented image is converted into 1 D vector as a feature vector to be given input to SVM. Also, for training set of images, Glaucoma and normal images are labelled as 1 and 0 for binary classification training.

The trained model is used to test the 3D reconstructed image for glaucoma detection.

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IV. RESULTS AND ANALYSIS

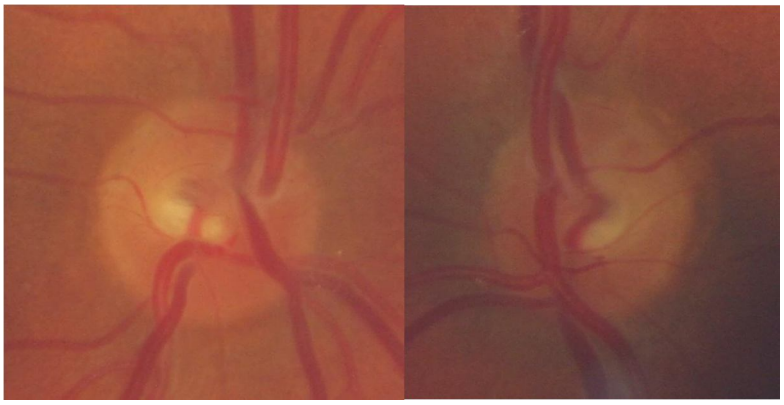

Figure: Stereophonic fundus images (Left and right) taken as input

Figure: 3D reconstructed image

The performance evaluated for 26 test images for Glaucoma detection. The performance is shown in table I.

Table I: prediction performance

Vector name	Actual Type	Result of the SVM	Nomination SVM
V1	Glaucoma	Glaucoma	TP
V2	Glaucoma	Glaucoma	TP
V3	Glaucoma	Glaucoma	TP
V4	Glaucoma	Glaucoma	TP
V5	Glaucoma	Glaucoma	TP
V6	Glaucoma	Glaucoma	TP
V7	Glaucoma	Normal	TN
V8	Glaucoma	Normal	TN
V9	Glaucoma	Glaucoma	TP
V10	Glaucoma	Glaucoma	TP
V11	Glaucoma	Glaucoma	TP
V12	Glaucoma	Glaucoma	TP
V13	Glaucoma	Glaucoma	TP
V14	Normal	Glaucoma	FP
V15	Normal	Glaucoma	FP

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V16	Normal	Normal	FN
V17	Normal	Normal	FN
V18	Normal	Normal	FN
V19	Normal	Normal	FN
V20	Normal	Normal	FN
V21	Normal	Glaucoma	FP
V22	Normal	Normal	FN
V23	Normal	Normal	FN
V24	Normal	Normal	FN
V25	Normal	Normal	FN
V26	Normal	Glaucoma	FP
Performance:			TP=11 FP=3 TN=4 FN=9

Table III shows the formulae for different parameters.

Table III: Parameters formulae

Parameter	Formula
Sensitivity	TP/(TP+FN)
Specificity	TN/(TN+FP)
Accuracy	TP+FN/(TP+TN+FP+FN)

Where TP=True Positive, TN=True Negative, FP=False Positive, FN=False Negative.

A. Performance Evaluation

Performance valuation is shown in table IV for the prediction of Glaucoma events.. The RNN based deep network shows better performance compared to all other classical classifiers.

Table IV: Performance evaluation

Classifier	Accuracy	Sensitivity	Specificity
SVM	0.86	0.55	0.57

V. CONCLUSION

A 3D reconstruction method based on the estimation of the pseudo depth map for ONH and a retinal image registration method based on the regional feature point matching are proposed in this paper. Both methods proved to be efficient as an image reconstruction or registration technique and could be taken into consideration as a low-cost preliminary examination way for screening examinations and treatment monitoring of retinal pathologies, or as a suitable tool to be integrated into automated retinal image analysis system for clinical purposes. Therefore in this paper we have performed various preprocessing techniques on fundus images and obtained from which it can be determined whether the eye is normal or with glaucoma and calculate performance parameters.

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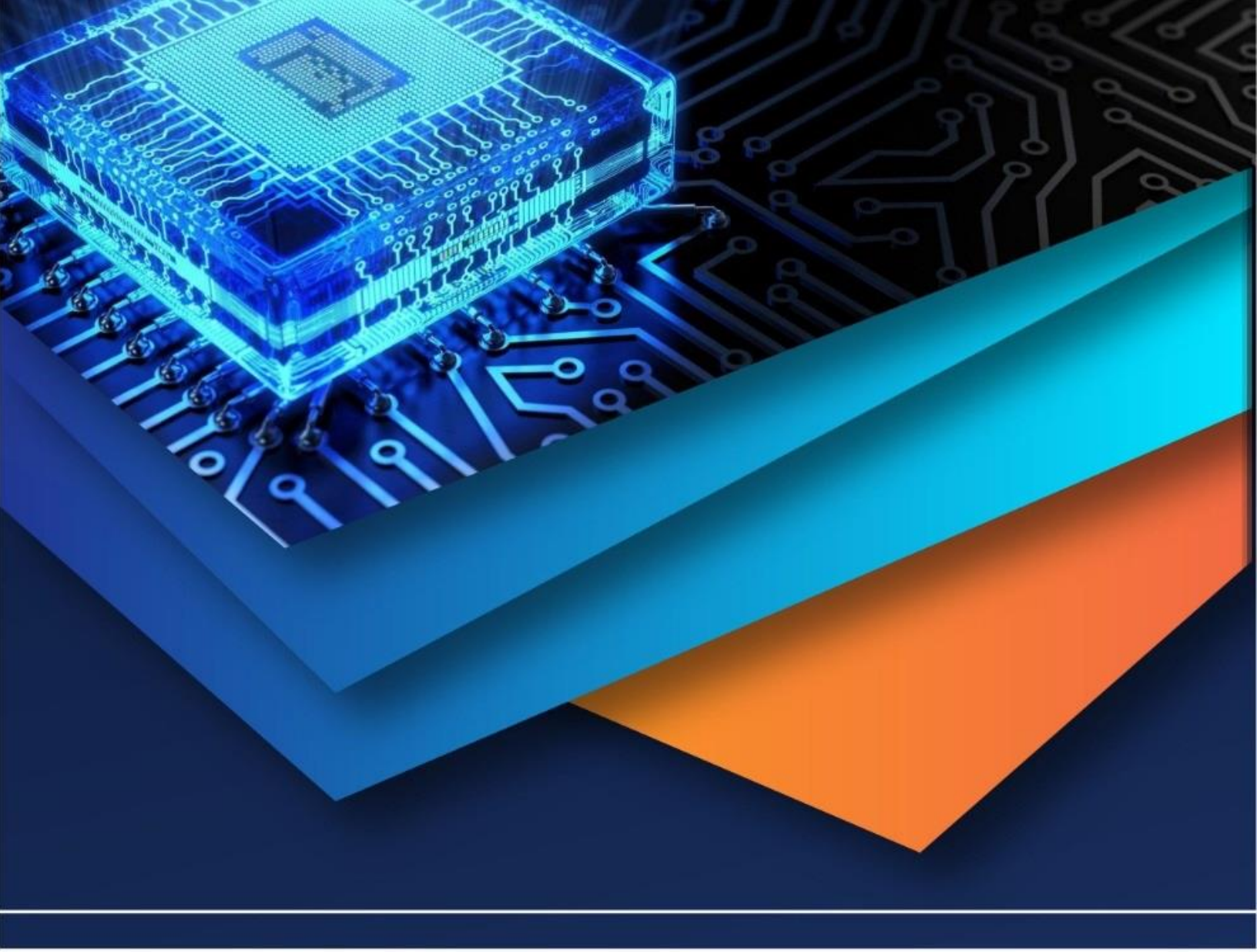

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