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3D Reconstruction of Human Retina from Fundus Image – A Survey

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ABSTRACT: *Imaging techniques for the eye include fundus camera, OCT etc of which the most widely used and economical one is the use of fundus camera. Images obtained from this camera are 2D in nature. Analysis of 2D data requires a lot of expertize. This makes it necessary for a 3D reconstruction of the 2D fundus image which would help doctors in their analysis and treatment plan. 3D retinal image would also be helpful in explaining to patients, the progression of disease. In this paper a survey on various methods for 3D reconstruction of retinal fundus image has been discussed.*

I. INTRODUCTION

A visual image is rich in information. 3D visualization technique is suitable for the display of complex structures. 2D visualization of images especially in medical images doesn't give significant information about the object and their properties, which are very useful in diagnosis and treatment. The 2D representation lacks showing different number of views, information loss due to lack of giving depth information of the object., doesn't give much information about the structure of the object, and lack of giving realistic effect. These drawbacks can be overcome by developing 3D models, that have an additional z direction which gives the depth information of the object which is very useful in medical image visualization.

The doctors can visualize a portion or area suspected to be infected by the disease in 3D view to examine the spread of the disease. Accurate diagnosis often requires a 3D image of retina. The analysis of the 3D shape of retinal fundus is required for identifying lesions and estimating the intensity of lesion. The produced 3D model of the eye can be used for studying the anatomy of the eye diagnosis of retinal disease, treatment planning and for educational purpose.

II. LITERATURE SURVEY

2.1 IMAGING TECHNIQUES FOR EYE

2.1.1 HYPERSPECTRAL FUNDUS IMAGES

A fundus camera is used to photograph the interior surface of the eye. Fundus cameras are used by optometrists and ophthalmologists for monitoring progression of a disease and diagnosis of a disease . Fundus image of retina provides physio-pathological information and is used to detect exudates and haemorrhages. The observation of fundus is used for diagnosis of eye diseases and also for checking the whole body conditions. Figure 2.1.1 shows the fundus images of human retina.

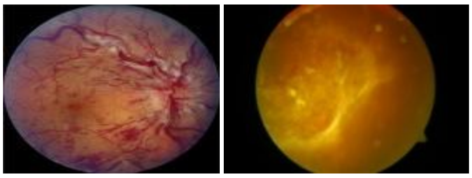

Figure2.1.1: Fundus images of human pathological retina

2.1.2 OPTICAL COHERENCE TOMOGRAPHY

Optical Coherence Tomography, or 'OCT', is a 3D imaging technique for obtaining sub-surface images of opaque materials at a low-power microscopic resolution. OCT has become a leading imaging method in displaying the structures of the eye .Figure2.1.2 shows the OCT images of retina. OCT is very useful for the medical community, because it provides tissue level information at higher resolution than other imaging modalities such as MRI or ultrasound. OCT image shows the quantity and configuration of macular holes, intra-retinal layers intra-retinal cysts and photoreceptor layer. Main advantage of using OCT is that it has no ionizing radiation.

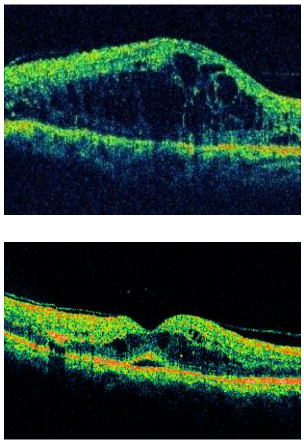

Figure 2.1.2 : OCT images of human retina

2.1.3 INTRAVENOUS FLUROSCENCE ANGIOGRAM (IVFA)

Intravenous **fluorescein angiography** (IVFA) is another imaging technique commonly used by ophthalmologists for evaluating the internal blood circulation of eye . IVFA is helpful in detecting leaks and abnormalities. IVFA are commonly used in certain cases of diabetic retinopathy and age-related macular degeneration. The photographic record of IVFA is called as fluorescein angiogram.

2.2 3D MODELLING TECHNIQUES

2.2.1 Y-FEATURE BASED METHOD

To obtain the 3-D shape of retina, practitioners generally use the specialized devices such as the scanning laser ophthalmoscope and the optical coherence tomography (OCT) system which provides a cross-sectional image of retinal fundus. The use of OCT is not widespread because it require costly equipment .Therefore the alternative method consists of inferring the 3-D shape of the retina using fluorescein images of the retina.

Existing literature reveals that atleast a pair of retinal images are required for 3D reconstruction of the retinal image. In Choe et al [1] paper, they 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.

2.2.1. 1 Y-FEATURE EXTRACTION

Y-feature are the regions where three vessels converge. seed positions of y-feature are located by using PCA based analysis for every pixel.The location with third largest eigen value are taken as the seed points. Y-feature has 8 DOF . And fit the model using gradient descent method by minimizing the energy.

$$f(x) = (-1)^m \frac{1}{2}\sum_{i=1}^{3}\int_{-wi}^{wi}\int_{0}^{l}[I(xi,yi)]^2 dldw$$

$$-\frac{1}{2}\sum_{i=1}^{3}\sum_{w\in(-wi,wi)}\int_{0}^{l}[G(xi,yi)]^2 dl -----(1)$$

Where i is the index of the arm considered, I(xi, yi)is the intensity ,G (xi,yi) is the gradient value . m=0 indicates dark vessel and m=1 indicates bright vessel.

$gj(\Theta)$ is the angle between each arm, bl and bu are the range values for angles and wl and wu are range values for widths.

$$B(\Theta,w) = \sum_{j=1}^{3}\left(\frac{1}{(gj(\Theta)-bl)(bu-gj(\Theta))} + \frac{1}{(wj-wl)(wu-wj)}\right)---(2)$$

$$\mathrm{E(x) = f(x) + \lambda B(\Theta, w) ----(3)}$$

λ is the trade off value. The energy function E is minimized using gradient method. Next step is to match the Y-features of source and target imge. For that consider two windows Za and Zb for source and target respectively

$$MI(Zz,Zb) = H(Za) + H(Zb) - H(Za,Zb) ---(4)$$

where H(Z) is the Shannon entropy of the window. After finding the mutual information homography and fundamental matrix are to be estimated.

2.2.1.2 ESTIMATION OF EPIPOLAR GEOMETRY

RANSAC method is used to detect the inliers among the matched pairs. And select the best four pairs to estimate the homography inorder to minimize the geometric error. Inorder to find the fundamental matrix plane and parallax based on RANSAC is used.

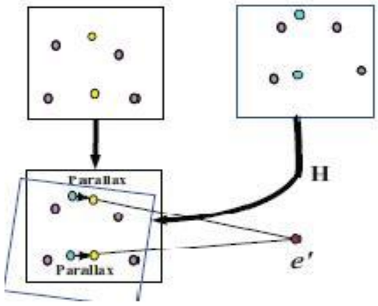

Figure2.2.1.2 estimation of fundamental matrix using plane and parallax method

$$F = [e^{'}]H$$

$e^{'}$ where is the epipole.

After calculating the fundamental matrix stereo images are rectified for the estimation of depth map.

2.2.1.3 STEREO MATCHING

Since retinal fundus has small depth variations ,disparity range is also very narrow. Search space is commonly taken as the maximum disparity gradient value. But this cannot be taken in the case of retinal images. We know the disparity at some key features so it is possible to find the disparity at other points since retinal surface is a smooth and curved surface. Inorder to estimate the depth map mutual information for matching points are used.

$$disparity = \max MI(d) = \max MI(Za, Zb, d)$$

Zb,d is the window with d pixel distance from Zb. The window pairs that has the maximum mutual information is used to determine the disparity of each pixel location. Inorder to avoid the staircasing effect in the disparity map of retinal images subpixel resolution is considered.

$$disparity = \max MI(d) = \max MI(Za, Zb, d)$$

Where
a=MI(disparity-1),
b=MI(disparity),
c=MI(disparity+1)

Each disparity is calculated individually by using mutual information mathching. By using this method different parts of retinal fundus such as fovea,optic disc lesions are accurately estimated.

2.2.2 RECONSTRUCTING 3D USING SEQUENCE OF ANGIOGRAMS

For reconstructing the 3D surface information of the human retinal fundus using a sequence of fluorescein angiograms is presented in [2] by F Laliberte .These angiograms are taken with an uncalibrated camera. In this work the camera is still and assuming that the natural head and eye movement is high to create different views as that of stereo. The results obtained shows the distribution of fluorescien with in the retinal fundus. This 3D fluorescien distribution obtained gives information about circulation and staining. This method is mainly concentrated on the macular region of retina rather than a full image. Data used include six sequence of angiograms of 3 patients having macular degeneration. The output obtained by using this method is a dense disparity map, dense disparity map is an image in which each pixel is the difference in distance between the corresponding part of two original images. The overall reconstruction procedure described in this paper include i) detection of control points and find the matching points between each image and the reference image. ii) calculate the disparity iii) rectification. Here the control points used are bifurcation points of the retinal blood vessels. For calculating the fundamental matrix eight point algorithm is used. The information obtained through the dense disparity map is same as the visual assessment done by the ophthalmologist.

2. 2. 3 3D RECONSTRUCTION BY REGISTRATION

Another method for 3D reconstruction which is based on registration is discussed in paper [3] . Here registration is based on both the area and feature in order to obtain an optimal solution and a translational model is estimated through binary mutual information instead of gray level mutual information. In this work a weak perspective camera is assumed because each retinal image has small depth variation. Then the geometric constraint of an eyeball is taken in to account to generate denser points for surface. Since the eyeball is approximated as a sphere a point based sphere fitting method is used. The author proposed a new algorithm for extracting blood vessels, it include matched filtering, local entropy thresholding ,length filtering and bifurcation and this algorithm does not involve any human interaction and less computational complexity. Prior to 3D reconstruction affine bundle adjustment is done to produce jointly optimal structure and viewing parameters and recovered a retinal euclidean surface

2.2.4 3D FUNDUS RECONSTRUCTION AND DISPLAY FROM MULTIPLE FUNDUS IMAGES

Koicchiro et al in paper [4] 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 maped 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. FINDINGS AND OBSERVATIONS

Existing 3D reconstruction methods require multiple fundus images , taken from different orientations. Since acquisition of image needs the patients concent and sometimes it may be difficult, and processing of images consumes a longer time. Reconstruction of single image minimizes acquisition and processing time. New methods have to be identified for reconstruction from single image. The authors are continuing their research in this field.

IV. CONCLUSION

An extensive survey on the various methods for 3D reconstruction of retinal fundus image has been discussed in this paper. These informations would be useful for researchers working in the field of 3D image reconstruction.

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REFERENCES

[1] Tae Eun Choe,Issac Cohen,Gerad Medioni,"3Dshape reconstruction of retinal fundus" *IEEE computer society conference on computer vision and pattern recognition.*,2006

[2] F. Labertéa, L. Gagnona, Y. Shengb R&D Department, CRIM, 550 Sherbrooke West, Montreal, QC, Canada, H3A 1B92 Physics Department, Laval University, Quebec, QC, Canada, G1K 7P4, "Three-dimensional visualization of human fundus from a sequence of angiograms"

[3] Thitiporn Chanwimaluang ,"Advanced retinal imaging: featureextraction, 2-D registration, and 3D reconstruction"

[4] Koichiro DEGUCHIt ,Z Junko NOAMIZ, Hidekata HONTANIZ ," 3D Fundus Pattern Reconstruction and Display from Multiple Fundus Images", *IEEE;* 2000

[5] M. Wunstel, H. Schumann, "Automatic 3D-reconstruction of the ocular fundus from stereo images", *Proc. Computer Assisted Radiology and Surgery*, pp. 456-60 ,2002

[6] Kitara Kadhim Al-Shayeh and Muzhir Shaban Al-Ani, "Efficient 3D Object Visualization via 2D Images", *IJCSNS International Journal of Computer Science and Network Security;* VOL.9 No.11, November 2009

[7] K. Deguchi, D. Kawamata, K. Mizutani, H. Hontani, K. Wakabayashi," 3D fundus shape reconstruction and display from stereo fundus images", *IEICE*

Transactions on Information and Systems, E83-D, pp. 1408-14 ,2000

[8] Kolar R, Kubecka ,Jan J ;"Registration and fusion of the autofluorescent and infrared retinal images". *Image and vision computing;* 2008

[9] Radim Kolar,Viktor Sikula,michal Base; " Retinal image registration using correlation" *BIOSIGNAL;* 2010

[11] France Laliberté, Langis Gagnon" Registration and Fusion of Retinal Images—An Evaluation Study" *IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 22, NO. 5, MAY 2003*

[12] A. Bartoli, P. Sturm "Nolinear Estimation of the Fundamental Matrix with Minimal Parameters*,", IEEETrans. on PAMI, Vol. 25, No. 3, March 2004*

[13] R. Hartley, "In Defence of the 8 point Algorithm", *ICCV1995, pp.1064-1070, June 1995*

[14] H. Hirschmüller, "Accurate and Efficient Stereo Processing by Semi-Global Matching and Mutual Information," *CVPR 2005, pp. 807 – 814, 2005*

[15] W.M. Wells III, P. Viola, H. Atsumi S. Nakajima, and R. Kikinis, "Multi-modal volume registration by maximization of mutual information*," Medical Image Analysis, vol. 1, no. 1, pp. 35–51, March 1996*

[16] A. Agrawal, R. Raskar, and R. Chellappa. What is the range of surface reconstructions from a gradient field? *ECCV (1)*, pages 578– 591, 2006

[17] L. Zhang, G. Dugas-Phocion, J. Samson, and S. Seitz. Single view modeling of free-form scenes. *CVPR01, pages I:990–997, 2001.*

[18] Yuji Iwahori, Takashi Nakagawa, Robert J. Woodham , Shinji Fukui, Haruki Kawanaka "Shape from Self-Calibration and Fast Marching Method" *IEEE,2008*

[19] F. Zana and J. Klein, "A multimodal registration algorithm of eye fundus images using vessels detection and hough transform,*" IEEE Trans. Biomedical Engineering, vol. 18, pp. 419-428, May 1999.*

[20] A. Can, C. V. Stewart, B. Roysam, and H. L. Tanenbaum, "A feature-based,robust, hierarchical algorithm for registering pairs of images of the curved human retina," *IEEE Trans. Pattern Anal. Machine Intell., vol. 24, pp. 347-364,March 2002.*

[21] D. Wu, M. Zhang, J. C. Liu, and W. Bauman, "On the adaptive detection of blood vessels in retinal images," IEEE Trans. Biomedical Engineering, vol. 53,pp. 341-343, February 2006.

[22] J. A. Sethian, "A fast marching level set method for monotonically advancing fronts," *Proc. Nat. Acad. Sci.*, 93(1):5– 28, 1998.