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A Study on Retinal Image Segmentation and Registration Methods

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ABSTRACT

Diagnosis and treatment of several disorders affecting the retina and the choroid behind it require capturing a sequence of fundus images using the fundus camera. These images are to be processed for better diagnosis and planning of treatment. Retinal image template matching is greatly required to extract certain features that may help in diagnosis and treatment. Also registration of retinal images is very useful in extracting the motion parameters that help in composing a complete map for the retina as well as in retinal tracking. This paper introduces a survey for the image preprocessing, dimensionality reduction, template matching and registration techniques that were reported as being well for retinal images.

Keywords : Retinal images, Registration, Segmentation, Motion Parameter Estimation, Real Time Tracking, template matching

I. INTRODUCTION

Retinal image processing is greatly required in diagnosing and treatment of many diseases affecting the retina and the choroid behind it [1], [2]. Diabetic retinopathy is one of the complications of diabetes mellitus affecting the retina and the choroid. In this condition, a network of small blood vessels, called choroidal neovascularization (CNV), arises in the choroid and taking a portion of the blood supplying the retina. As the amount of blood supplying the retina is decreased, the sight may be degraded and in the severe cases, blindness may occur. The physicians try to treat this dangerous disorder by applying optical energy to photocoagulate the neovascularization. Argon laser is used in photocoagulation purposes to cauterize the small vessels which increases the amount of blood supplying the retina and thus maintaining the sight. This treatment modality is achieved in many sessions. The physician asks the patient to fixate his/her eye to be able to direct the laser beam to the affected area. The current success rate of this procedure is below 50% for eradication of CNV following one treatment session with a recurrence and/or persistence rate of about 50%. The latter condition requires repeating the treatment. Each treatment repetition in turn has a 50% failure rate. Moreover, several studies indicate that incomplete treatment was associated with poorer prognosis than no treatment [3], [4]. Consequently, the need to develop an automated laser system to treat the whole retina in one session has become a necessity. This system is intended to scan the retina and track it applying the laser energy to whole area except the sensitive objects that may be damaged by the laser energy. The system is assumed to do this by capturing the retinal images using a fundus camera. These images are to be accurately segmented to extract the sensitive objects in the retina such as the blood vessel tree, the optic disk, the macula and the region between the optic disk and the macula. The positions of laser shots are to be distributed in the rest of the retina. Also a robust registration technique is to be applied to detect the motion parameters of the retina to update the positions of laser shots accordingly. [5].

Moreover, the fundus camera can only provide an image for a portion the retina but not the whole retina. The physician sometimes needs to have a complete image for the retina to be able to have a reliable diagnosis and hence plan for good treatment. This problem may be overcome by some image processing algorithms to build a complete map for the retina. In this paper, we collect most of the image denoising, template matching, segmentation, dimensionality reduction and registration techniques that were reported to be the best for retinal images. These algorithms were applied to our images to confirm its validity and accuracy.

II. LITERATURE SURVEY

The survey clearly explains the concept of various processes of retinal images

A. Survey on Retina Image Preprocessing

A main problem encountered by medical imaging systems is the distortion of visual signals obtained due to imperfect acquisition and transmission errors. Visual distortion may arise due to various factors like time of exposure, lighting, and movement of eye and sensitivity of the imaging devices. These affect images in terms of contrast, distortion and artifacts introduced, blur and contrast sensitivity. These visual changes have negative impact and make the image complex for interpretation. This necessitates image enhancement techniques that improve quality parameters. Examples include histogram equalization, image sharpening, contrast adjustment, edge enhancement and denoising. Image preprocessing techniques include image contrast enhancement, image noise removal, threshold, edge detection and image segmentation.

Image pre-processing is the primary procedure of digital fundus image. Noise in the medical images has two disadvantages. They degrade the image quality and obscure the important information required for accurate diagnosis. Both have serious impact during analysis and have to be handled in an efficient manner. Thus all medical images need an algorithm to enhance the image and help the medical practitioner to diagnose quickly and efficiently.

Marco et al. (2005) [6] has used the compensation based technique for eliminating the luminosity and contrast variations in the retinal images. Normalization of these variations is performed by estimating the non-uniformity in the background part of the image. However, few zones with “non-background” dark areas larger than 50% are not affected by this normalization.

Aliaa et al. (2006) [7] has presented a comparative study between various contrast enhancement techniques for retinal images. These techniques are implemented on publicly available databases and the results are tabulated. These results analyze the merits and demerits of the various contrast enhancement techniques.

Peng et al. (2007) [8] has used the transform based techniques for edge enhancement in low contrast images. The output images are based on the non-linear function which incorporates the effects of noise. A comparative analysis is also performed with other techniques. The significance of red channel for accurate color retinal image processing is explained by Nancy et al. (2007).

Segmentation of retinal blood vessels is performed with red and green channels of the retinal image and the results are compared with the segmented output of the green channel of the retinal image. Experimental results have shown promising results for the usage of red channel for retinal image segmentation. A comparative analysis of the pre-processing techniques in color retinal images is performed by Salvatelli et al. (2007) [9].

George et al. (2008) [10] has implemented a derivative based technique for background foreground differentiation. The convolution of 2D Gaussian kernels with the second derivatives of the input image is performed to highlight the blood vessels. But the drawback of this system is the low accuracy results specified in the report.

Gopal et al. (2008) [11] has proposed a domain knowledge based blood vessel enhancement technique in colour retinal images. A correction factor is derived from the estimated degradation and used in this work to minimize the contrast and luminosity variation in retinal images. A model based vessel enhancement technique is proposed by Yuan et al. (2008) [12]. The background suppression measure, smoother 'vesselness' measure and the responses at crossings are superior to the conventional methods. Directional field based retinal vessel enhancement technique is reported by Jian et al. (2008) [13]. A single step brightness normalization and neighborhood enhancement is used in this work.

Multi scale line operation based blood vessel enhancement is performed by Farnell et al. (2008) [14]. This multi scale line operation algorithm is based on region growing technique and the results are compared with the conventional median filtering technique. The proposed technique is applicable for all retinal disease classification applications and the results also revealed that the proposed technique is much faster than the conventional techniques.

During past decades, many methods have been proposed to handle the medical image segmentation problems using unsupervised clustering methods. However, the methods have some limitations to overcome the problems of image such as intensity inhomogeneity, partial volume effect, heavy noises and other artifacts during the segmentation process. Among all other mathematical based segmentation methods, Fuzzy C-Means has received much attention since it gains the original information from image itself and it does not require any prior information to process the segmentation system. Fuzzy C-Means is the method of fuzzy clustering technique. Fuzzy clustering is one of the most important techniques in cluster analysis. Over the years, there have been many methods and techniques developed to perform cluster analysis. Most traditional cluster analysis methods are crisp partitioning, in which every given object is strictly classified into a certain group. However, in practice, the class attributes of most objects are not strict and also ambiguous; hence it is not suitable for hard partitioning. Auspiciously, the fuzzy set theory was proposed by Lotfi. A. Zadeh [15]. It is an extension of classical set theory, and it provides a powerful tool for soft partitioning. The idea of using fuzzy set theory [5] for clustering is firstly, introduced by Ruspini [15]. Since fuzzy clustering obtains the degree of uncertainty of samples belongings to each class and expresses the intermediate property of their memberships, it can more objectively reflect the real world problems. Recently, Fuzzy clustering technique [16] is widely applied in many applications such as medical diagnosis, pattern recognition, data analysis and image segmentation. Since it does not require any prior information about the objects of data and any human interference of images, it is an important tool in analyzing the behavior and structural complexity of images in medical image segmentation [17]. Fuzzy clustering process is carried out effectively by using FCM algorithm [18].

B. Survey on template matching and registration of retinal images

Several works on template matching of retinal images is based on more general image registration methods, which have been comprehensively studied in recent years. However, general retina registration methods focus on matching image pairs that both have a large FOV with local deformations or different image modalities. The existing retinal template matching algorithms are limited to detecting specific objects from the image, where the template always contains a certain feature, such as the optic disc, exudate and artifacts [19]–[20].

Retinal image registration itself is challenging: the nonvascular surface of retina is homogeneous in healthy retinas, while exhibiting a variety of pathologies in unhealthy retinas [21]. Retina images captured by adapter-based optics provide less information and have low image quality, which further increases the difficulty of template matching. It is instructive to introduce current retina image registration methods which can be used for template matching and their feasibility in addressing our stated problem. Retina image registration approaches can be classified into area-based and feature-based methods. Feature based methods optimize the correspondence between extracted salient objects in retina images [21]. Typically, bifurcations, fovea, and the optic disc are common features used for retinal image registration. A small FOV template has little probability of containing specific landmarks on the retina, thus the fovea and optic disc are not applicable. Vascular bifurcations are more common, while similarly, the small amount of bifurcations in the template cannot form the basis of a robust registration. Besides, the extraction of the vascular network in poor quality images is difficult. It can cause ambiguous vascular directions when label the bifurcations. General feature point based approaches are also implemented in retina registration, such as SIFT-based [22] and SURFbased methods [23]. These approaches can register the images in complex scenarios and are computationally efficient. They assume the feature point pairs can be reliably detected and matched to estimate the transformation. Although feasible in most cases, the process can fail on low-quality retina images without enough distinct features. Area-based approaches match the intensity differences of an image pair under a similarity measure, such as SSD (sum of squared differences) [24], CC (Cross-Correlation) [25] and MI (mutual information) [26], then optimize the similarity measure by searching in the transformation space. Avoiding pixellevel feature detection, such approaches are more robust to poor quality images than feature-based approaches. However, retina images with sparse features and similar backgrounds are likely to lead the optimization into local extrema.

Because ophthalmology is largely dependent on visual information, it is an ideal specialty for telemedicine [27]. Digital capture of images and the potential for transmission of these images via electronic transfer across large distances with subsequent image analysis offers the potential for more efficacious use of medical resources in large, rural communities that may otherwise have difficulty obtaining expert opinion [28]. The most common system utilised in 'tele-ophthalmology' is "store-and-forward", where images are captured, and later transmitted electronically to be analysed at a later date. This contrasts with live video-conferencing, which is currently limited by electronic transmission rates. "Tele-ophthalmology" could be utilised between primary health care practitioners, optometrists and ophthalmic specialists, or between different ophthalmic units. Telemedicine has even been used to aid prison medical officers in diagnosing ophthalmic complaints, and thus reducing costs and potential complications of prisoners attending specialist medical centres [29]. In a collaborative international project, telemedicine has been found to be cost effective in reducing the burden of eye-disease, and that richer countries may aid capacity building in health care systems of poorer countries. Countries with large areas of sparsely populated communities such as Canada, Australia and India may greatly benefit in terms of health care delivery to these areas.

Telemedicine has a potential role in diabetic screening. Kawasaki et al. (2003) [30] report that 1076 of 1170 eyes' fundal images were successfully evaluated by a consultant ophthalmologist, when images were transferred through electronic mail. Lin et al. (2002) [31] report single non-mydriatic monochromatic wide-field digital photography of the disc and macula to be more sensitive for diabetic retinopathy screening than mydriatic ophthalmoscopy, when transmitted electronically to a reading site. When adjudicated by standard seven-field colour photographs, the higher sensitivity of digital photography primarily reflected the reduced sensitivity of ophthalmoscopy in detecting early retinopathy. TOSCA (Tele-Ophthalmological Services Citizen-Centred Application) was developed in Europe as a project to reduce the incidence of blindness caused by diabetic retinopathy (Luzio et al., 2004) [32]. Telemedicine has been explored in screening for ROP. Yen et al. (2002) [33] found RetCam (Massie research Laboratories, Inc., Dublin, CA) images captured by a neonatal nurse compared well with examinations performed by an experienced ophthalmologist with good sensitivity, but only moderate specificity. In addition, teleophthalmology has been utilised in macular diseases.

Eikelboom et al. (2000) [34] report on the effect of JPEG and wavelet digital image compression on the quality of images for telemedicine. JPEG image compression breaks the image into blocks of 8×8 pixels and converts these blocks into spatial frequency components. Sampling of this frequency domain information by closely preserving the low-frequency components and approximating the high-frequency components is performed and the amount of information discarded determines the amount of compression. Wavelet employs band filters and low pass filters to the pixel rows and columns of an image. This produces information on the low-frequency components of the image and the horizontal, vertical and diagonal detail in the image (and is more computationally intensive). Eikelboom et al. found that wavelet compression to 15 KB for digital image transmission was ideal when time and costs are to be minimised. For computational time to be minimised, the use of JPEG compression to 29 KB was a good alternative.

All studies to date using telemedicine in ophthalmology have not extended the digital process to digital image analytical techniques. This may be difficult due to the need for relatively high-resolution images in order to perform quantitative digital image analysis. Transmission of such high-resolution images is currently impractical for telemedicine. However, image compression algorithms are currently still evolving and with improved technology, it may be possible to transmit sufficiently high-resolution images to enable digital image analysis.

C. Dimensionality reduction on retinal Images

There are numerous dimensionality reduction techniques. We can divide them into two main categories: the linear methods which linearly transform input feature space and non linear methods. Non linear methods assume the existence of low dimensional manifolds on the basis of which the input data is localized and describe the transformed data by their positions on the discovered manifolds.

The best well known examples of linear methods are: 1) Principal Component Analysis (PCA) [26], which finds the linear combinations of input variables with the greatest variances, 2) Independent Component Analysis (ICA) minimizing statistical dependency between transformed components [27], and 3) Linear Discriminant Analysis (LDA). LDA is a supervised method, which means that the input data has to be grouped into classes. LDA finds linear combinations with best possible discrimination between the input vectors of different classes [28]. It is strongly related to the class selections and cannot be performed automatically – the multispectral images have to be labeled by class values, prior to the reduction. The extension of the PCA is the Kernel Principal Component Analysis (KPCA). KPCA maps the original space on the basis of kernel function, which allows us to take its non linear properties into consideration [29]. Other most often used nonlinear reduction methods are Isomap and Local Linear Embedding (LLE). Isomap applies Multidimensional Scaling (MDS), which preserves the distances between objects in the lower dimensional spaces. The geodesic distances in the original space are considered by the Isomap. LLE assumes local linearity of the input space and reconstructs each sample by the linear combination of its neighbors. In the final step of LLE, the determined weights are mapped on the embedding global coordinates.

The machine learning techniques require a trainset, the set which is the base for the exploration and data mining of the input feature space. For the linear dimensionality reduction it determines the coefficients of linear transformations and for the non linear reduction it allows to discover manifolds. In case of the spectral space reduction of multispectral There are many applications of dimensionality reductions. We briefly enumerate only a few of them. In [30] and [31] the linear PCA and ICA methods are used for the motion capture skeleton model parameters and binary silhouettes extracted from the video images. In [32] the silhouettes are reduced by Isomap. The sequences of reduced human poses are classified by Dynamic Time Warping, Hiden Markov Models and on the basis of extracted sequence features. The application of Kernel PCA to pose classification is presented in [33]. Dimensionality reduction is a major step in the most system of face recognition: linear [34] and non linear [35] methods are used. Dimensionality reduction is also applied in areas such as: analysis of the stock market [36], detection of the network attacks [45], biomedical datasets analysis [37], palmprint recognition [38], hand and finger tracking [39] and many others.

There are of course numerous examples of spectral dimensionality reductions. In [40] spectrally segmented regions of hyperspectral plant images are transformed by PCA for further classification. In [41] ICA method is used for the hypersepctral remote sensing imagery classification. Similar approaches dedicated to land cover detection and geological investigations by Isomap and LLE are presented in [42] and [43]. We apply classical linear Principal Component Analysis and nonlinear Kernel Principal Componet analysis. The Isomap and LLE are rejected because of the limitation associated with the global trainset.

III. INFERENCE FROM EXISTING WORKS

The eye provides a unique opportunity to image internal biological tissue in vivo and many diseases can be diagnosed and monitored through ocular imaging. For example, diabetic retinopathy is a common retinal complication associated with diabetes, causing microaneurysms, exudates and haemorrhages on the retina [2]. Changes of retinal arteries and veins, as well as their ratios, can be indicators of hypertension [3]. The timely detection of these pathological changes via regular retinal screening and analysis is particularly important for early diagnosis and prevention.

High quality fundus images of the retina are traditionally acquired in a laboratory setting with expensive and cumbersome equipments. Acquiring high quality fundus images poses a challenge for patients in rural and other underserved areas who must overcome significant hurdles to receive regular checkups in the clinic. Visiting an ophthalmologist often is not convenient for people in the city as well.

In contrast, emerging portable and low-cost fundus cameras allow fast, accessible imaging of the retina, albeit with a decrease in image quality. Using portable fundus cameras outside the clinic connects rural patients with their doctors [4], [5]. By daily retinal monitoring and trend analysis of the data, ocular disease may no longer be considered the silent disease, as early onset is likely to be detectable and even predicted [6].

A typical example of such fundus cameras is clip-on lens adapters attached to smart-phone systems [4], while these consumer-grade optical devices have two main disadvantages: small FOV and lower image quality than lab-based fundus cameras. These disadvantages can be rectified by template matching and registration process.

Retinal template matching and registration is an important challenge in teleophthalmology with low-cost imaging samples. So the effectiveness of retina match becomes more difficult task. Further, with noise being present in the images, retinal matching is difficult to be analyzed. Hence further research is done by using new image denoising approach based on the clustering algorithm. In addition, proposed work nearest template of the retina image is performed by using various approaches have been used with area-based registration, providing a robust approach. To the best of knowledge, this is the first template matching algorithm for retina images with small template images from unconstrained retinal areas.

IV. CONCLUSION

In this work, a survey of retinal image segmentation and registration methods were applied on retinal images to be an assisting tool in the diagnosis and treatment of retinal disorders. At first, we applied different segmentation algorithms on the reference images to extract the sensitive objects including blood vessel tree, optic disc and macula and the region between them. Then, a binary image is composed which contains the sensitive objects as white objects in a dark background. Secondly, we applied many registration algorithms for the purpose of detection of motion parameters in retinal images considering the less time and accurate results.

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