

Retinal Image Registration Using Intensity Values and Bifurcation Structure

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Abstract: Retinal image registration is important for applications such as diagnosis and treatment in ophthalmology system. The process by which obtaining correspondence between digital images of the same retina but in different viewpoints. Methods for the registrations are difficult because the variation in structure and intensities. Retina is the only part in human body where the blood vessels can be directly visualized. This method is combining the feature based method and intensity of the particular points in blood vessel structure. Considering the bifurcation structure formed by the blood vessels consisting of one main points and three neighbor points connected to it. Twelve angle values and three length components are used to find the characteristic vector of a single structure. Matching of these characteristic vectors of two images is more accurate and efficient than conventional point matching methods. Combining the intensity values along with the structure makes it more accurate hybrid method of retinal image registration.

Keywords: Retinal Image registration, Bifurcation structure, Characteristic vector, Intensity values, Transformation

1. Introduction

Image registration is a process by which information present in different images can be combined to form fused images. Retina is a light sensitive tissue lining the inner surface of the eye. The image of the visuals created on the retina. The retina consists of interconnected network of neurons [1]. The surface of neurons lined with photosensitive cells called photoreceptors. The basic structure of the retina consists of the optic disk, macula, fovea and vasculature. The optic disk is an oval shaped bright disk where all the blood vessels appear to converge. Digital images of the retina can be classified as temporal images [8] and multimodal images [8]. Multimodal images which are taken by different modalities such as Red-Free images, Fluorescent Angiography, Indocyanine Green Angiography. Temporal images of retina are images taken at different times these type of images are used to identify the progression of diseases. The main challenges involved in retinal image registration are (1) Radial distortion occurred when imaging curved retina. (2) Change in image modalities and change in intensity of images taken at different times. (3) different camera parameters (4) Imaging setup parameters may vary according to the requirement of clinical expert. (5) distortions in retinal surface due to some disease, etc.

By using this registered retinal image doctors can easily identify the diseases [2] such as diabetic retinopathy, hypertension, glaucoma, arteriosclerosis and retinal occlusion etc. The requirement for high quality and fast image registration algorithm for registering multimodal retinal images is increasing day by day. There are different methods available for registering retinal images based on different features of the images. The blood vessels and its structure is mainly used for feature based retinal image registration because this structure is not varying with time. In retinal image registration one image is considering as the reference image [10] or base image and the other image is transformed with reference to the base image. Feature based registration methods are either point matching method or area/region matching methods. In point matching method [8] features of some particular points are selecting for

registration. For example considering the angles around the blood vessel joining points. A branch of blood vessels makes a minimum of three angles around a particular point. Values of these angles are used to match the corresponding points in the other image. This method has some problem because there may be multiple points having the same angle values that will lead to miss matching of the points.

The region/area [8] based method in which considering the features of a particular region. The blood vessels form a bifurcation structure [8] which includes one master point and three connected points. The bifurcation structure contains the values of twelve angles in the structure and values of the three branch lengths. These values are used to calculate the characteristic vector of the structure. Transformation model is determined by using the characteristic vector. Matching and registration of the two images is based on the transformation model of bifurcation structures present in both the images. The similarity metric between the transformed image and the base image is determined by mutual information. Transformation models include linear, affine, projective transformations. The mutual information [10] is an entropy based technique where the joint histograms of two images are found which in turn is used to compute the probability density function. The probability of occurrence of one image metric over the other image and the probability density function are determined and the resulting best angle of rotation. Combining the vessel based bifurcation structure and non vessel based mutual information helps to improve the accuracy and efficiency of the registration algorithm.

2. Proposed System

Registration can be defined as the process of transforming one of the images into the coordinate system of the reference image. Given retinal images $a(X)$ and $b(X')$ where $X = (x_1, x_2, \dots, x_n)$, $n=2$ and $X' = (x'_1, x'_2, \dots, x'_n)$ for 2-D images. The goal of registration is to find a transformation function t that establishes pixel to pixel correspondence between these two images.

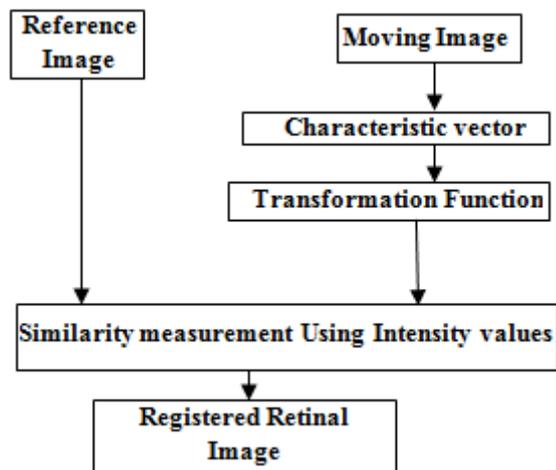


Figure 1: Retinal Image Registration Process

$$t : a(X) \rightarrow b(X') \Leftrightarrow t(a(X)) = g(X')$$

The transformation function t defines the deformations to be applied in the image to make it compatible with the reference image. This deformation may include rotation, shifting, scaling, etc. The image taken as the reference is called the base / reference image and the image to be transformed is known as moving image [1].

3. Retinal Image Registration

A number of steps involved in the process of retinal image registration. First process is to extract the area of interest from the original fundus image [1] of retina. The interested area in this registration algorithm is blood vessel structure. From the extracted image select the candidate bifurcation structures. The bifurcation structure consists of one main point and three other points connected to it. Considering the 12 angular values made by the connecting points and length between the points and the main point.

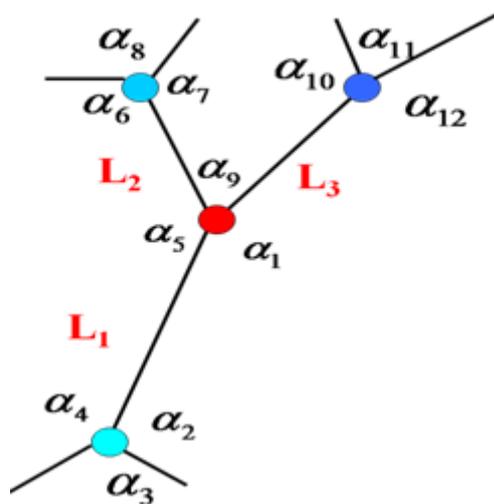


Figure 2: Bifurcation Structure

Using these values calculating its characteristic vectors each bifurcation structures. The characteristic vector of each bifurcation structure can be defined as $y = [l1, l2, l3, a1, a2, a3, a4, a5, a6, a7, a8, a9, a10, a11, a12]$

where li and ai are the normalized length and normalized angle respectively. The characteristic vectors are used to find the matching pairs. Bifurcations structures of the moving image may have the correspondence with one, none or multiple structures in the reference image. There are different methods proposed to solve the ambiguous matches such as Bayesian framework [6], region-based cross-correlation [7], and intensity profile [5]. Here the intensity values of the points are used for finding the similarity of the points Transformation function is applying with reference to these points. The transformed image is combined with the original image to form the registered image

3.1 Extraction

Extraction is the process of selecting the blood vessel structure required for the registration from the original image of retina. This is done by a sequence of operations on the retinal image. First process is to adjust the intensity values of the image. Then find the edges in the grayscale image followed by morphological operations like dilation, closing rare performed to obtain a clear image. Then trace region boundaries in binary image. Eliminate the edges by morphological opening. As a result of these operations binary image of the blood vessel structure is generating.

3.2 Finding feature points

Feature points (bifurcation points) are the points where three branches of the blood vessel structure joints together to form a junction. The angle made by the branches and length of each branch is considered as the main feature for registration. Thinning operation is performing on the binary image to get fine blood vessel structure. Calculating the position of candidate points using some image processing operations and marking them using square grids.

3.3 Selecting appropriate candidates

Vessel structures are the most important representatives of the retinal image. Traditional methods reasonably describe how the vasculature is distributed on the surface of the retina but they are inadequate for the registration of images. To characterize the vasculature in a better way, it is important to find a dense set of landmarks which indicate time varying changes in the vessel profile. The landmarks should be both meaningful and available in plenty. The vessel junctions and cross over points would be a sufficient to compare with the other image. Bifurcation points are the points having the one master point and three neighbor points. The candidate points will connect to the neighbors and finding the points having three neighbors.

3.4 Finding angle vectors

Computing the bifurcation angle of the selected points and calculating the angle vector of the points using some morphological operations. Calculating the characteristic vector for each selected bifurcation structure using three branch length and angle values. The structure-matching method is executed to find the initial correspondence between the images. These initial matched candidates are

used to estimate the transformation model that is to be applied in next step to register the image.

3.5 Feature matching

Transformation model is used to calculate the feature matrix. Then matching algorithm executed to match the best points in the feature matrix of the two retinal images. It is done by using mean and circular shift operations. It needs further constraints such as location or blood vessel width to refine the results [3]- [4]. Then the transformation models are to be applied to the detected bifurcation structures of image pair to find best matching features. There are linear, affine and quadratic transformation and found that the affine model is enough and robust to describe the transformation. This transformation model requires a minimum of two matching pairs [8]. In a bifurcation structure there are four feature points so it is enough to use the basic transformation

3.6 Matching Verification and Registration

Geometrical transformation has to be applied to the input image. The transformation function extract the bifurcation coordinates from node and transform the original image with respect to the reference image. This function verifies the correspondence and select the best matched pairs. As a result of these functions the best angle of rotation for the transformation of image will generate. The matching criterions can be optimized ether using the Generic algorithm [10] or by the simulated annealing method [10]. Generic algorithm is an optimization technique that selects the matching points that is fit for the registration. The optimization techniques consider the intensity values of the matching points.

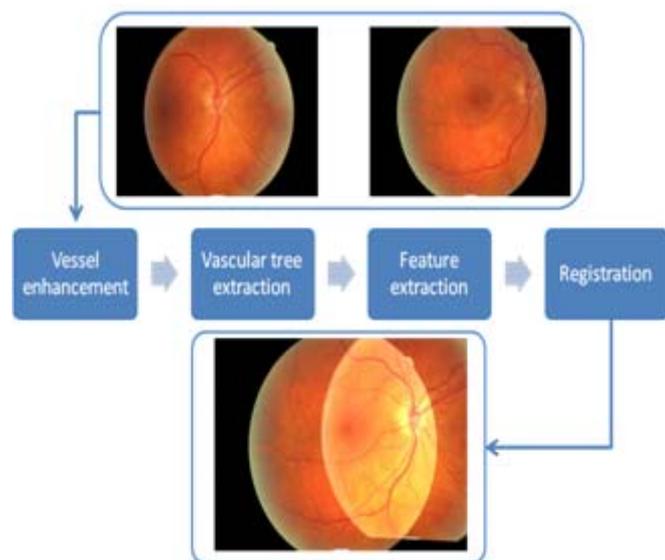


Figure 3: Retinal Image Registration Process

4. Experimental Results

A large set of retinal images are collected from the different websites related to medical images. The dataset includes the images of retina that affected by some disorders like retinal occlusion, diabetic retinopathy etc. Then the collected data set is classified and few images are selected for initial study.

First and important step in retinal image registration is the extraction [9] of the vasculature structure because the selection of bifurcation structure depends on the extracted image. Different algorithms were implemented to extract the binary image of the blood vessel structure.

Table 1: Extracted Blood vessels

Reference image	Input Image	Bifurcation structure 1	Bifurcation structure 2

The table shows the extracted set of images from base image and reference image. The feature points are also marked with a square in each structure. These points connect with its neighbor points using a link function to generate the bifurcation structure. Bifurcation structure is selected for registration because it is invariant against translation, rotation, scaling, and even modest distortion. The location and feature vector of each structure is calculating with the mathematical equations. The selected features and its position is used to geometrically transform the base image with respect to the reference image.

There are different transformation models like linear affine, projective, similarity etc. Each of these transformation types will generate different type of registered images. From the experiments conducted with the collected datasets, the affine transformation is correct for almost all the images in the collected data set. The combined image of the blood vessel structure is also generating for the convenience.

5. Conclusion

The registration of retinal images is critical because of its vascular structure and non-uniform illumination. These factors have complicated the process when this registration technique is purely vessel based or non vessel based. Feature-based retinal image registration method based on bifurcation structure-matching. It is invariant against translation, rotation, scaling, and even modest distortion. It can deal with the registration of retinal images when vasculature-like pattern is identifiable, even partially. The simplicity and efficiency of the proposed method make readily to be applied alone or incorporated with other existing methods to formulate a hybrid or hierarchy scheme. That means integrating intensity information with the bifurcation structure that will reduce the computational time and increase accuracy

6. Future Scope

As an enhancement a hybrid method which incorporates vessel and non vessel based registration method. . The study can be extended by adding the other features with the structure and intensity like the position of joining points, width of the blood vessels etc. This can improve the accuracy of retinal image Registration.

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