"A JAVA-Based System for Segmentation and Analysis of Retinal Images"

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Abstract

This paper presents a platform independent system, RetinaView, that is designed for manual analysis as well as automatic segmentation and characterization of multi-modality retinal images and videos. A user-friendly interface that allows display of individual retinal images in four or more windows has been designed for simultaneous viewing of multiple modalities in research-based retinal studies. A variety of tools have been developed for RetinaView, including automatic segmentation of retinal vasculature, segmentation of small vascular abnormalities found in early stages of diabetic retinopathy (microaneurysms), segmentation of drusen, lesions pathoneumonic of age related macular degeneration (ARMD), analysis of fluorescein and indocyanine green videos, and manual annotation capabilities and fovea location. This system will enable ophthalmological researchers, clinicians, ophthalmologists to study, diagnose, and monitor the progression of pathologies in retinal images with much greater precision than is possible with totally manual techniques. This paper presents an overview of the RetinaView system and gives examples of its application in segmentation of normal anatomical features as well as pathological lesions.

1. Motivation

Ophthalmologists, whether they are clinicians or researchers, would benefit greatly from a user-friendly, computer-based tool that would enable them to concurrently visualize multiple modalities of retinal images to diagnose, analyze, and monitor changes in the presentation of the patient's pathologies. Although a number of retinal image analysis systems have been reported, there is a need for an inexpensive tool that exploits the progress that has been made by various retinal and medical image processing investigators [1, 2] by implementing and testing these algorithms on clinical data. Currently, expert retinal reading centers that analyze diseases such as ARMD and diabetic retinopathy use semi-quantitative methods in their grading of the images. The timeliness of expert retinal graders to fully quantitate areas of individual lesions is prohibitive, and parameters that are commonly measured are integrated details of the whole image, such as determining the size of the largest drusen in one particular retinal sub-region. Determining the rate of disease progression through the use of exacting quantitative measures, such as auto-segmentation, facilitate correlation of specific lesion growth with such primary outcomes as visual function. Clinical trials of new pharmacologics utilizing digital retinal imaging will depend on analysis of the images and ultimately change detection of the involved lesions.

2. Background

RetinaView is a JAVA-based system developed for the purposes of providing a means for very precisely characterizing retinal images. It was developed in JAVA to make it a platform independent system. Figure 1 shows a screen dump from retina view where you can view multiple modalities of retinal images simultaneously. In the future it can be operated over the web by making use of the power of JAVA. Presently, trained individuals, graders, are tasked with screening and analyzing retinal images for clinical reasons, research, or for drug studies.

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They face an enormous task of evaluating the images manually for pathologies in the retina. RetinaView has powerful segmentation algorithms [3, 4] that automatically segment lesions associated with diabetic retinopathy and age-related macular degeneration. For segmenting micro-aneurysms, RetinaView uses a morphological filter to segment candidate lesions. Drusen are segmented using similar morphological filters, but employs a novel pre-classification for determining the morphological parameters. Registration is performed automatically for six different modalities, including red free, infrared, autofluourescence, standard color images, and fluorescein angiogram (FA) and indocyanine green (ICG) videos. The approach used is to register all modalities of a patient to a single universal base FA image using mutual information and fourier transform technique.

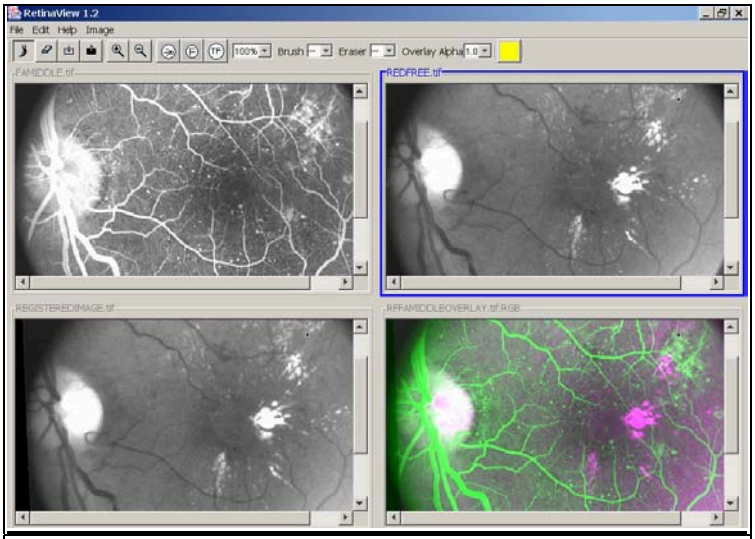
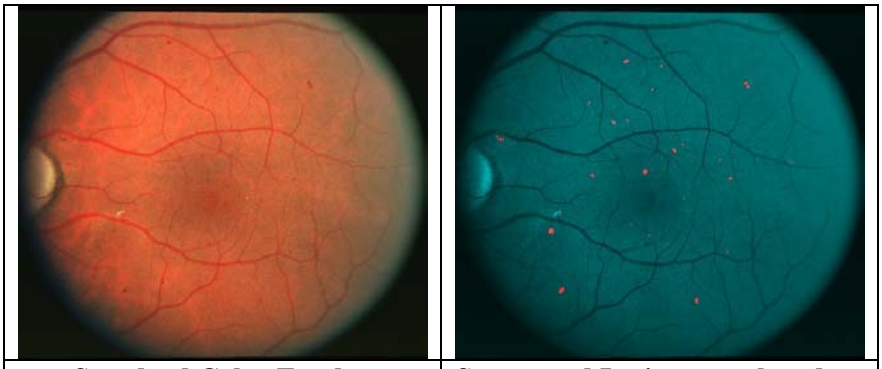


Figure 1. Displaying different modalities of Retinal Images in RetinaView.

3. Segmentation of Microaneurysms

Segmentation of microaneurysms was performed to the green channel image of a standard fundus photograph [5, 6]. The images were first pre-processed to enhance the contrast and to correct the uneven illumination on the image. Secondly, the retinal vasculature was extracted out using morphological filters. Depending on the field of view the optic disc was also removed from the image. This image is again filtered using a tophat morphological filter and thresholded to get the candidate microaneursyms. Using shape filter and grey level information of the detected objects the noise is removed to get the microaneursyms. Figure 2 shows an example of the segmentation algorithm performed on the green channel.

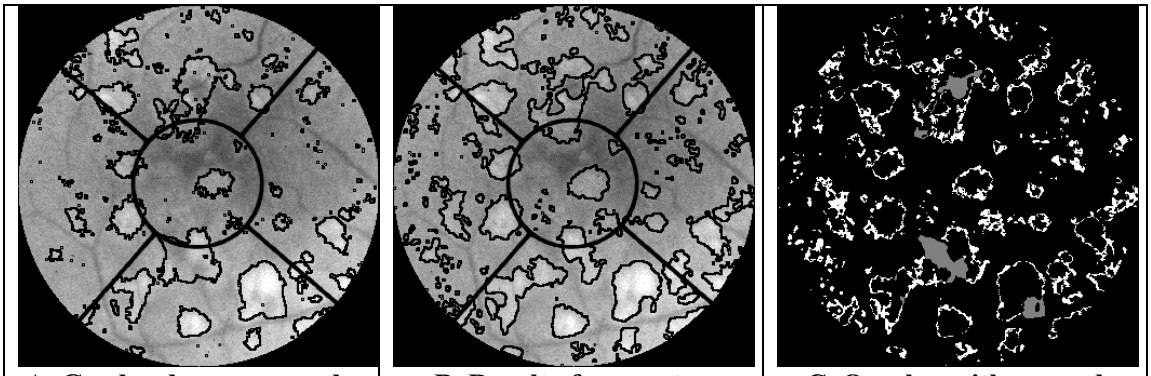


Standard Color Fundus Photograph	Segmented Lesions overlayed on top of green channel

Figure 2. Segmentation of microaneurysms on color fundus photographs.

4. Segmentation of Drusen

A computer-based algorithm has been developed and tested to provide the ability to track very precisely the position and margin of the ARMD associated lesion, drusen. Variations in the subject's retinal pigmentation, size and profusion of the lesions, and differences in image illumination and quality present significant challenges to most segmentation algorithms. An algorithm, based on mathematical morphology, was used for the segmentation. The innovation is that the process first classifies the image as to the stage of the disease in order to optimize the variables that must be specified within the mathematical morphology. Figure 3 presents an example of the segmentation.



A. Grader drawn ground truth | **B. Result of computer segmentation** | **C. Overlay with ground truth as 50% gray and computer as black**

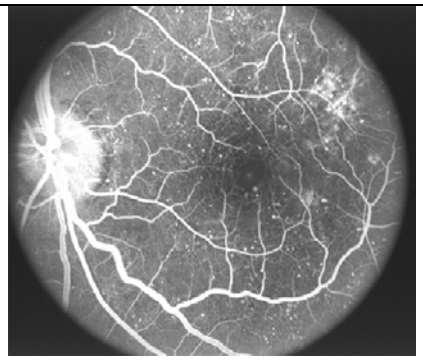
Figure 3. Example comparing hand drawn ground truth with automatic segmentation.

5. Multi-mode Registration

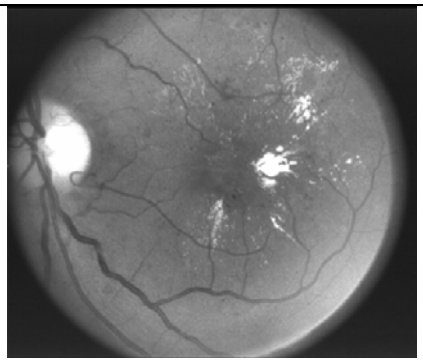
To perform automatic registration, we implemented a mixed algorithm that operates directly on the images. When registering images from different modalities, we found that using the same method does not guaranty good results. The images need to be preprocessed differently: a median filter is applied for AF images to reduce the noise level; Gaussian smoothing is performed in order to equalize the image intensity, some images needs to be inverted (veins appear black in AF, but white in other modalities).

First, a Fourier-based method is applied to detect rigid shifts in the images. However, this method cannot be used to detect local shifts. The second step is to construct a set of tie-points between the base image and the target image. The tie-points are determined using mutual information values between areas surrounding these points (templates). The resulting set of tie-points is processed, to eliminate mismatched points (based on low correlation values or large shifts from the base points). A LWM (local weighted mean) 3rd order polynomial morphing function is the used to construct the registered image.

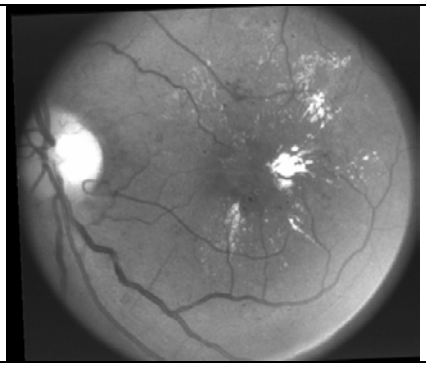
Figure 4 presents registration of one image from red free modality to a fluorescein angiogram image. The parameters used were: template size of 50x25 pixels, over 200 tie-points, LWM morphing function with N=6 number of points to infer each polynomial.



A. Base Image, FA modality



B. Target Image, Red Free modality



C. Morphed image

D. Morphed image and base image, overlaid

Figure 4. Multi-modality automatic registration of retinal images and videos.

6. References

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