VISUALIZATION OF THE RETINA LASER IMAGES IN MATLAB

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Abstract

Acquisition and processing of the retina laser images has been growing for over 10 years. This article deals with 2D/3D visualization of this data in Matlab. Because of noisy images and non-uniform illumination, some necessary steps are needed before the visualization. First results of ongoing research are presented and also the suggestions for future research are proposed.

1 Confocal laser scanning ophthalmoscope

The laser retina examination has an increasing importance over the glaucoma diagnosis methods. This method is based on the confocal scanning laser ophthalmoscope (CSLO), that uses a small laser beam over the retina (or its part) to obtain a 2D image of reflections from defined depth. By focusing the laser beam we are able to measure reflections from different depths and obtain a set of 2D images; the part of retinal volume. There are several CSLOs; one of the most used is Hiedelberg Retina Tomograph (HRT), that is shown on Figure 1.

Figure 1: The Hiedelberg Retina Tomograph

A laser is used as a light source (670 nm). The laser beam is focused to one point of the examined object. Some portion of light is reflected, separated from the incident laser beam and detected. In order to produce 2D images, the incident beam is deflected in two dimensions perpendicular to the optical axis. The CSLO enables to detect reflection from the planes parallel to the optical axis, that means into depth (Figure 2a). So, it enables a true 3D imaging.

HRT examination has several advantages. The main advantage is high acquisition rate. 2D optical section images are acquired within 32 ms, with repetition rate of 20 Hz. The images are

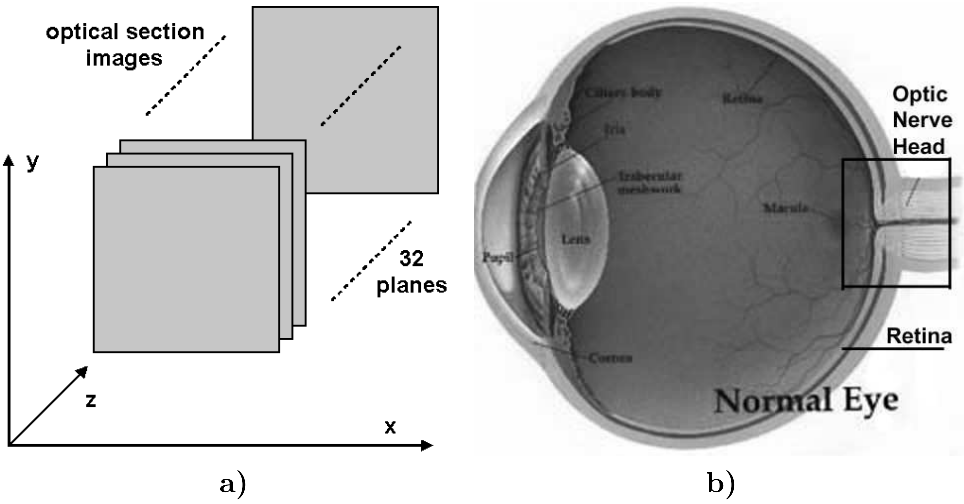


Figure 2: a) 32 planes parallel to optical axis. b) Eye anatomy; the treated volume is depicted by the square.

digitized in frames of 256×256 picture elements. The total acquisition time of a 3D image is about 1.6 seconds. Next big advantage is that pupil dilatation is not required. And finally, HRT images has big resolution. The digital resolution is from 10 μm to 20 μm per pixel and 16 μm to 128 μm per plane.

2 Glaucoma diagnosis

The optic nerve head examination (see Figure 2b) by CSLO has an increasing importance in glaucoma diagnosis. This methods has been developed to separate glaucomatous eyes from normal eyes and to detect early glaucomatous damage of the optic nerve head [6]. In addition, methods for follow-up the glaucomatous progession also has been developed [1, 2]. Therefore, the HRT has a broad scientific background. The convenient presentation of 3D data is therefore very important.

In the next part we will discuss the HRT data preprocessing and the visualization in Matlab.

3 Data preprocessing

Figure 3 shows 32 planes acquired by HRT. We can see that the planes illumination vary with depth and also within the plane. So, the first step in preprocessing algorithm is correction illumination. We have used the simple histogram equalization method [3] and method based on the estimation of background illumination [4]. The latter was found as a more convenient. The results obtained by this methods are shown on Figure 4. Unfortunately, both methods also enhance background noise as can be seen from the pictures.

Therefore, the second preprocessing step is noise suppression. A simple 3D median filter [5] was used for noise suppression. The 3D window for median computation was set to $[3, 3, 3]$. These values seems to be a good choice because no significant edge degradation occur (see Figure 5). The main disadvantage is the big computation requirement.

4 Data visualization in Matlab

As we have performed the preprocessing steps, we have to present the diagnostic information appropriately. There are two important parameters that should be obtained from 3D data:

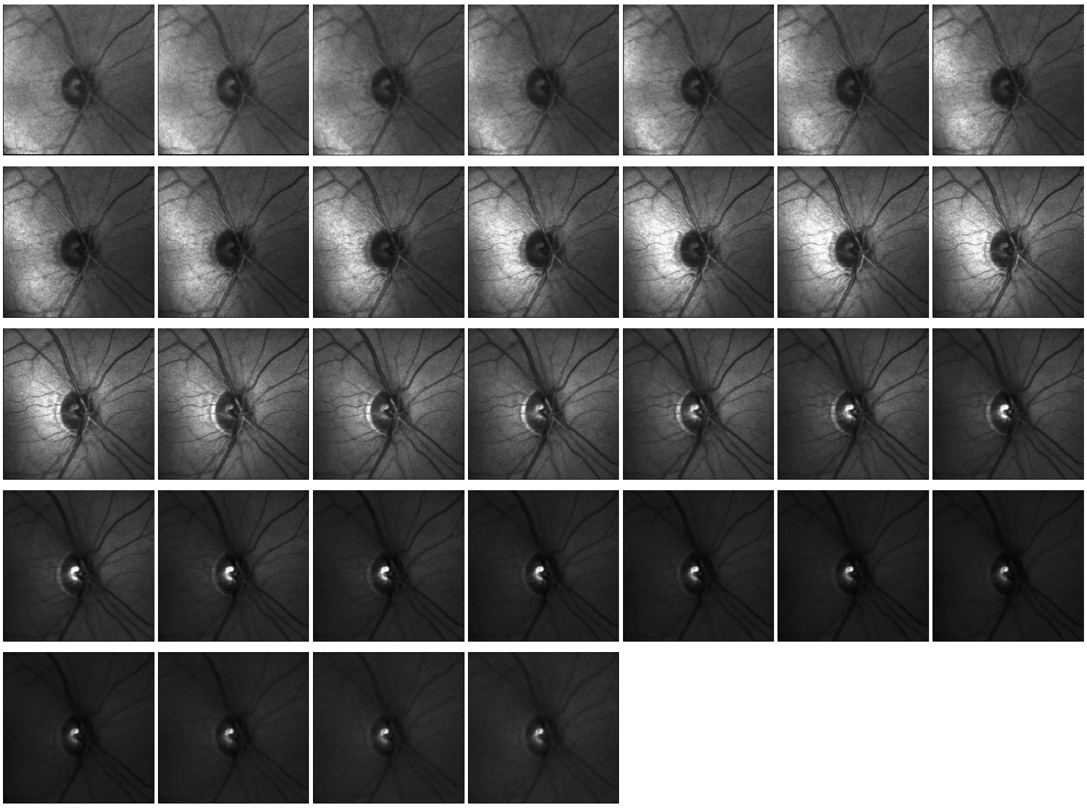


Figure 3: 32 planes obtained with HRT

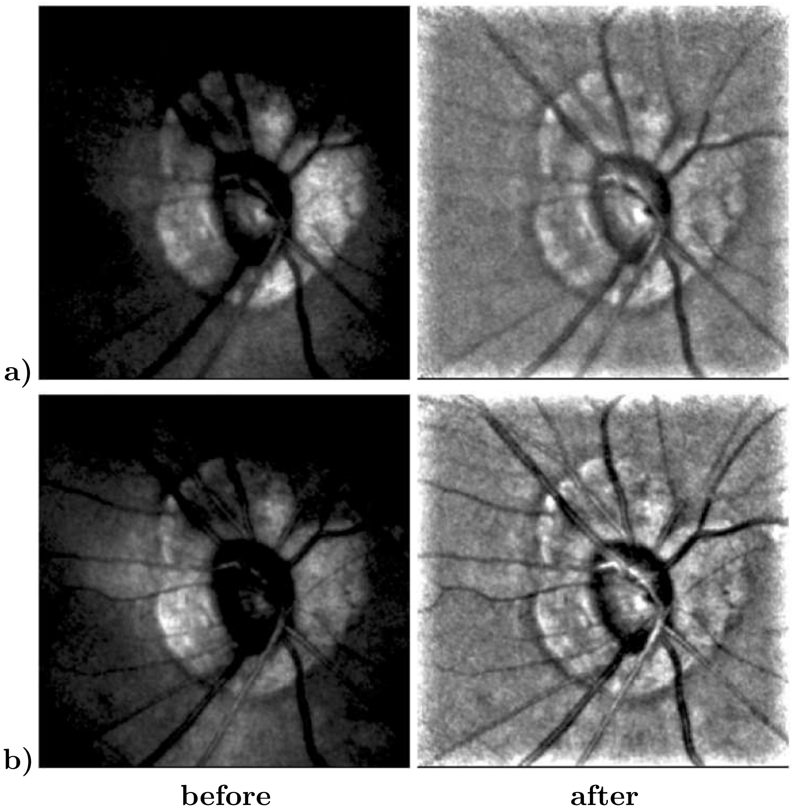
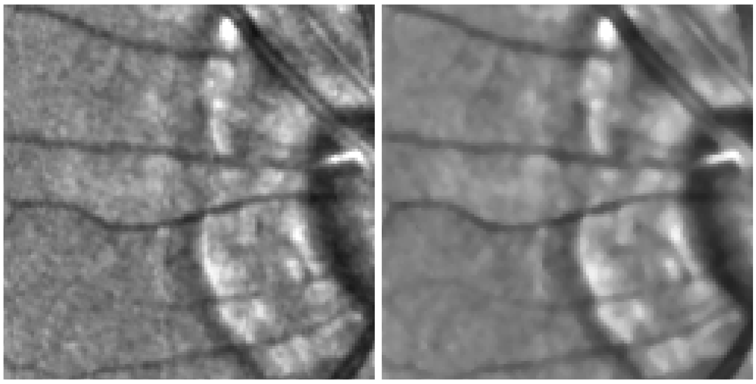


Figure 4: (a,b) Picture shows two scans before (left) and after (right) correction illumination.



a) **b)**

Figure 5: (a) Original part of one scan and (b) 3D-median filtered part of the same scan.

1. Maximum intensity through the scans - this is proportional to the reflectivity of the layers;
2. Position of the maximum intensity - this indicates the position of the most reflective layers;

Both parameters can be extracted very simply with *max* Matlab function, but it takes several seconds on *Pentium III/733MHz*. Figure 6 shows the Z-profile, the values of pixels along the 32 planes. We are searching for the maximum and its value. These parameters describe the topography of optic nerve head. Once we have extracted these two parameters, we are read to

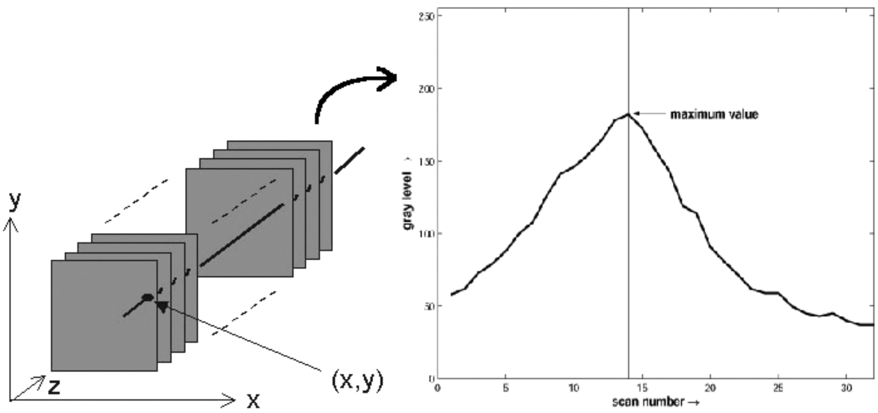
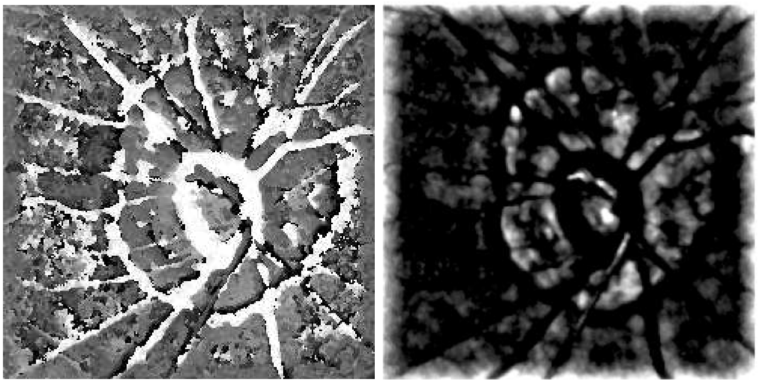


Figure 6: Z-profile: the gray levels through the planes

display them. One possibility is to display them as 2D image with *imshow* function as shown on Figure 7. Another possibility is to use the 3D imaging with *surf* function and others function for defining the view, light, render method and so forth. The Matlab code for this imaging is presented here:

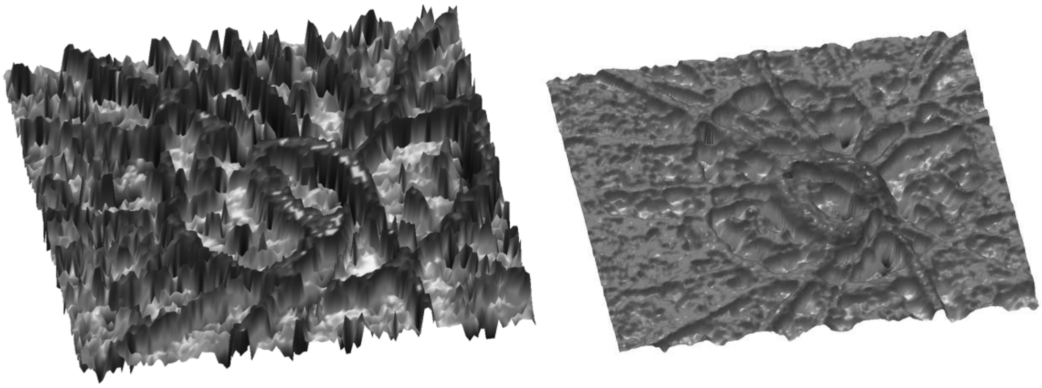
```
function RetinaRenderer( img )
        h = figure(1);clf;
        surf( fliplr(img) );
        set( h, 'Renderer', 'OpenGL' );
        axis([0, size(img,2), 0, size(img,1)]);
        set(gca,'Position',[0.01, 0.01, 0.98, 0.98],...
        'AmbientLightColor',[1 1 1] );
        view( 170, 80 );
        shading interp;
```



a) b)

Figure 7: The parametric images: (a) the positions of maximal values and (b) the maxima values.

```
lightangle( 15, 80 );
set( findobj(gca,'type','surface'),...
        'FaceLighting','gouraud',...
        'AmbientStrength',.5,'DiffuseStrength',.8,...
        'SpecularStrength',0.8,'SpecularExponent',25,...
        'BackFaceLighting','unlit');
```



a) b)

Figure 8: The parametric images shown as in 3D space: (a) the positions of maximal values and (b) the maxima values.

5 Discussion and conclusion

The method for CSLO data visualization has been presented. The algorithm can be summarized as follows:

1. Illumination correction - background illumination model;
2. Noise suppression - 3D median filter;
3. Data extraction;
4. Visualization - Matlab routines for 2D/3D imaging;

The presented results shows the effectiveness of Matlab for data visualization. However, the preprocessing step is necessary for good visualization results, because of noise.

The 3D median filter seems to be very useful for this noise suppression in spite of its simplicity. From presented images, one can see that the edges of blood vessels remain sharp and the noise background is suppressed. Implementation of this filter involves three *for* cycles, that is extremely time consuming, particularly in Matlab. Deeper analysis of these kind of images must be done, particulary the laser noise. This is an important step before any preprocessing and visualization.

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References

[1] Quantitative Three-Dimensional Imaging of the Posterior Segment with the Heidelberg Retina Tomograph, ©Heidelberg Engineering GmbH, Heidelberg, Germany

[2] The Heidelberg Retina Tomograph II, ©Heidelberg Engineering GmbH, Heidelberg, Germany

[3] Gonzales,R.C., Wintz,P. Digital Image Processing, Second Edition, Addison-Wesley, 1987

[4] Chastek,R., Michelson,G.,Donath,M. Wolf, and Niemann,H. Vessel Segmentation in Retina Scans, In Analysis of biomedical signals and images, Proc. of 15th International EURASIP conference Biosignal 200,pp.252-254,2000

[5] Nikolaidis,N., Pitas,I. 3-D Image processing algorithms, John Wiley Sons, 2001

[6] Flammer,J. Glaukom, Triton, 2003

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