A Fully Automatic Framework for Segmentation and Localization of Retinal Structures in Fundus Images

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Background and Purpose

Segmentation and localization of retinal structures is an essential pre-processing step for many applications of **fully automatic** or computer aided medical diagnosis.

In this work, we propose a framework for localizing and segmenting the most important retinal structures in color fundus images:

- **vascular tree**
- **optic nerve head**
- **fovea region**

Methods: Pipeline

The processing pipeline is the following (see Fig. 1):

1. Vessel segmentation using the **Hessian matrix based vesselness feature** to extract the vascular tree.
2. A modified **Fast Radial Symmetry Transform (FRST)**[1] to estimate the optic nerve head (ONH) position and diameter
3. **Fitting a double ellipse model**[4] onto a calculated vessel density map through the optic nerve head **to estimate the macula location**
4. Refinement of macula localization by **analyzing the local region of interest**

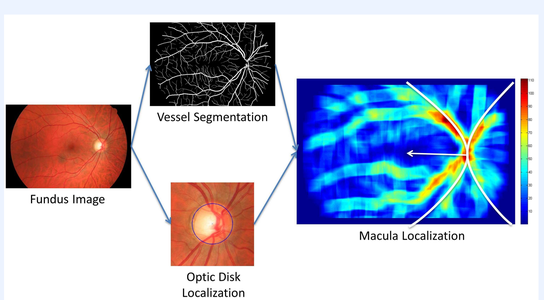

Figure 1: Processing pipeline for segmentation order of the main retinal structures

Methods: Vessel Segmentation

Our vessel segmentation[2] is a multiscale method using the vesselness feature (see Fig. 2):

1. **Histogram stretching and denoising** using bilateral filter
2. **Iterative down sampling:**
   - Highest resolution is the input resolution
   - Further lower resolution images are obtained by rescaling the last image with a factor 0.5
3. **Vesselness extraction** in each image
4. **Backsampling** to the input resolution
5. Binarization using **hysteresis thresholding**
6. **Fusion** of images by pixel-wise operator
7. Postprocessing using **mathematical morphology**

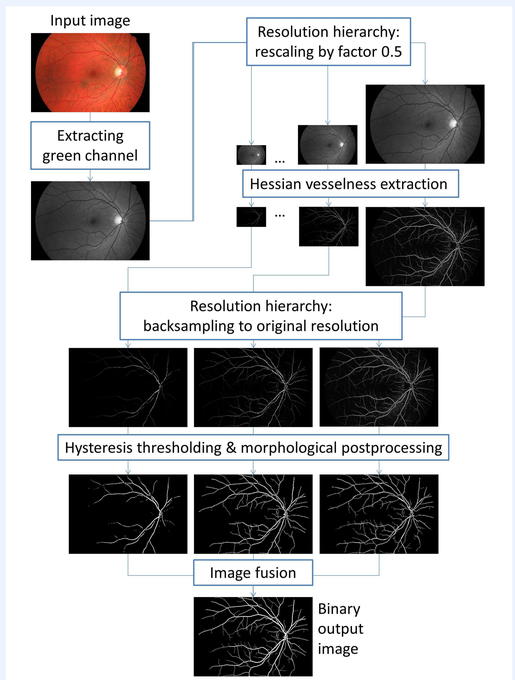

Figure 2: Pipeline of the vessel segmentation method

Methods: Optic Nerve Head Localization

The optic nerve head is localized by a modified FRST. Our modifications[3] are the following:

1. **Denoising** and elimination of small vessels from the image using median filtering
2. **Upper-bound constraint** introduced **to the gradient** in the accumulator map to neglect edges of vessels
3. **Global maximum selection** over all maxima at each map to estimate ONH diameter

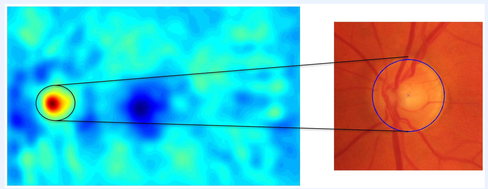

Figure 3: ONH localization: FRST map (left) and the localized region in the input image (right)

Methods: Estimating Macula Location

The following method uses both the vessel tree and the ONH to estimate the position of the macula region:

1. **Calculating vessel density map** from segmentation
2. **Fitting a double parabola model**[4] onto the main arcs in the density map through the optic disk center
3. The rough estimated macula position is **2.5 Optic Disk Diameter (ODD) far from the optic disk** center on the symmetry axe of the parabolas
4. The position estimation improved by finding the **maximum in a calculated vessel distance map** in a local ROI

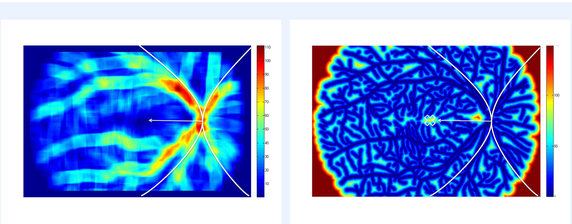

Figure 4: Rough estimation of the macula region by fitting a model(left), and the refinement of the localization(right) finding the local maximum

Experiments and Results

Each method was tested on 45 images (resolution: 3504×2336 pixels) of the public available high resolution fundus (HRF) database (www5.informatik.uni-erlangen.de/research/data/fundus-images/), and the results are compared to a manually generated gold standard:

1. Vessel segmentation accuracy: $\mathbf{0.96 \pm 0.006}$
2. Optic nerve head localization error: $\mathbf{0.05 \pm 0.07ODD}$
3. Model based macula localization error: $\mathbf{0.39 \pm 0.13ODD}$
4. The refined macula localization error: $\mathbf{0.12 \pm 0.06ODD}$

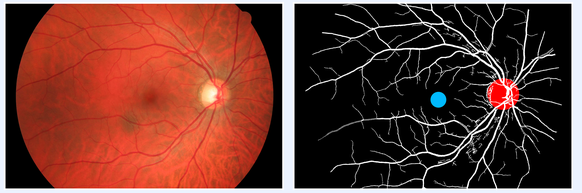

Figure 5: An example input image(a) and the segmentation results(b): the segmented blood vessels are white, ONH is red and the macula position is marked by a blue circle

Conclusion

Our methods show high accuracy in localization of the vascular tree, the ONH, and the macula. Thus, the framework **can be used effectively to aid medical diagnosis** by providing segmentation and localization of important retinal structures in fundus images.

Support

The authors gratefully acknowledge funding of the Erlangen Graduate School in Advanced Optical Technologies (SAOT) by the German National Science Foundation (DFG) in the framework of the excellence initiative and the International Max Planck Research School: Physics of Light.

Commercial Relationship

A. Budai, None; K. Mogalle, None; L. Laurik, None; J. Hornegger, None; G. Michelson, None

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