Exercise 3

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Vesselness Filtering, Bilateral Filter

1 Vesselness Filtering

In this task we will perform multi scale vessel enhancement filtering [1] to segment the vessels in a retinal fundus image. Changes in the vessel topology and shape can be indicative of retinal disease such as diabetic retinopathy. Download the files "vesselness_ex.m" and the provided images from the exercise material page. Complete the MATLAB script to implement fully functional automatic vessel segmentation. [1] and the script from the lecture provide the neccessary details and equations.

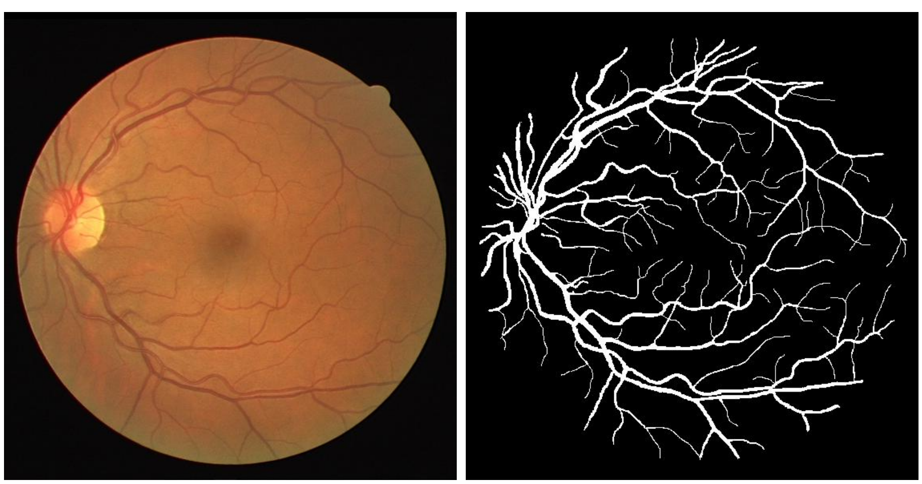

Figure 1: Color fundus image (left) and a corresponding manual vessel segmentation (right)

This consists of the following steps:

1. Loading of the fundus image and the associated mask image
2. Extraction of the green color channel, thresholding, intensity inversion
3. Multi-scale vessel enhancement filtering including:

(a) Smoothing the image using a Gaussian with succesively larger σ
(b) Computation of the second derivatives
(c) Finding the Eigenvalues of the Hessian matrix at every pixel
(d) Calculate the two parts of the Vesselness equation R_b and S
(e) Calculate the vesselness value itself
(f) Combining the vesselness values from the different scales by use of the maximum

4. Thresholding the vesselness image to generate a binary image

2 Bilateral Filter

The bilateral filter[2] is an edge-preserving filter. It takes not only the spacial distance to a neighbor pixel into account but considers also the similarity of neighboring pixels. In theory, all pixels of the image contribute to the value of a filtered pixel (see lecture script). We consider only a neighborhood of size $2 \cdot n + 1$ around a pixel (x, y). So the formlua for the filter can be rewritten to:

$$\vec{h}(x,y) = \frac{\sum_{\xi=-n}^{+n} \sum_{\upsilon=-n}^{+n} f(x-\xi, y-\upsilon) \cdot c(x,y,\xi,\upsilon) \cdot s(x,y,\xi,\upsilon)}{k(x,y)}$$

k is a normalization defined by

$$k(x,y,) = \sum_{\xi=-n}^{+n} \sum_{\upsilon=-n}^{+n} c(x,y,\xi,\upsilon) \cdot s(x,y,\xi,\upsilon)$$

- Download the MATLAB files "bilateral.m" and "bilateralFilter.m" as well as an image, for example a picture of the computerscience tower: http://www.informatik.uni-erlangen.de/img/hochhaus.jpg
- The closeness c is already given as the distance weighted by a gaussian with σ_C.
- Use as similarity measure s the intensity difference weighted by a gaussian with σ_S.
- Optional: Extend the bilateral filter to color images. Use as similarity measure the norm $||\cdot||_2$ of the color difference weighted by a gaussian.

3 References

1. "Multiscale vessel enhancement filtering", Alejandro F. Frangi, Wiro J. Niessen, Koen L. Vincken, Max A. Viergever, 1998
2. "Bilateral Filtering, for Gray and Color Images", Tomasi, Roberto Manduchi 1998

4 Useful MATLAB commands

eig, gradient, fspecial, imfilter, im2bw

We will work interactively on the implementation of the above mentioned tasks!