CS 7960, Advanced Image Processing
Spring 2010, Prof. Guido Gerig

Project 1: Scale-Space Selection

Out:	Thursday Feb-11-2010
Due:	Thursday Feb-24-2010
Office hours:	Tue 1pm to 3pm, please contact me in advance or for other arrangements.

Required Readings: Papers and Materials Anisotropic Diffusion
Additional information: "Medical Image Analysis" Notes West Virginia, CS 593 791, available on WebCt and on my web-page under Lecture "Anisotropic Diffusion"

1 Nonlinear scale space by anisotropic diffusion

You need to implement the anisotropic diffusion partial differential equation as a forward-in-time-centered-space (FTCS) discrete implementation. The implementation is in its spirit as you find in the paper and as discussed in the class.

$$\frac{\partial I}{\partial t} = \mathrm{div}(c(x, y, t)\nabla I)$$

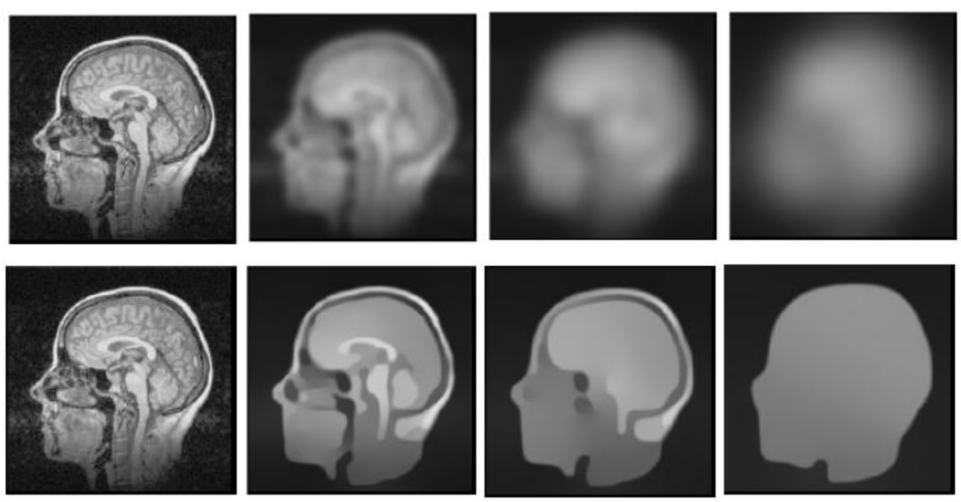

Figure 1: Example of scale space representations from linear diffusion (top) and nonlinear diffusion (bottom).

The filtering has two parameters, the time t which is proportional to the number of iterations, and the parameter κ of the conductivity function. Remember that the degree of smoothing is not linear with the time t, but logarithmic (see FEV Chapter 3 discussion 3.3 on cascading property and 3.7 on binomial coefficients, i.e. if you see each step as a convolution you can get a feeling how the resulting variance and the standard deviation changes!).
Remember our discussion that the value κ serves as an "edge threshold", i.e. selecting edge strengths that are preserved where others are blurred.

A possible strategy for your program is outlined below:

- Implement a numerical solution to the partial differential equation of the anisotropic diffusion.
- Use the common conductivity function (Gaussian) as shown in the Perona and Malik paper.
- Similarly to Perona and Malik's paper, best is not only to compare the resulting images but the edge maps. Looking at your code, you see that at every iterations, you actually calculate the local gradient and can easily calculate the gradient magnitude. Your program can output the images but also the gradient maps.
- Read a test image, be creative about an image that would be interesting to smooth while preserving edges, which is an image that can be segmented by subdivision into homogeneous patches.
- Experiment with different κ-values and same number of time steps to observe different levels of details that are preserved or disappear, respectively. Show results with images and gradient maps.
- Experiment with your choice of an interesting κ-value and different number of iterations, to observe the evolution of nonlinear scale space. Show results with images and gradient maps. Remember that κ is related to the local gradients. Could you think about a concept to automatically choose this parameter based on your image?
- Remember that you can simulate linear scale-space by setting the κ-value very high, which means much higher than the expected largest gradient maginitudes.
- Compare the nonlinear scale space (with a few key images taken from the log-scaled number of iterations) with linear scale space. Show results with images and gradient maps.
- Discuss how such a nonlinear smoothing could help with the segmentation of one or few images selected by you. E.g., how could you make use of the κ-value to select the components you want to segment, and how could you make use of the

You should write up a report summarizing your procedure and discussing your results. The report should be **written in html** and **accessible to the instructor via a web-browser**.

- Description of method to implement the PDE of the anisotropic diffusion.
- Description of the conductivity function you choose.
- Application to images that you select as images that might benefit from such a procedure.
- Description and illustration of smoothing performance under different κ-values and iteration numbers, as detailed above.
- Discussion of preservation of details, i.e. different κ-values selectively preserve different details, which might be useful for specific segmentation task (like e.g. segmentation of text lines into words and then into characters, just as an analogy).

- Discuss criteria mentioned in James Fishbaugh's lecture as advantages and disadvantages of linear versus nonlinear smoothing (blurring, edge sharpness, edge-dislocations, causality (no new structures created with scale), simplification of implementation and more.

- Commentary about any issues that arose, ways for alternative implementations, potential improvements etc.