CMP 717 – Practical 1: Nonlinear Diffusion

Due date: Friday, 13-11-2020, 11:59 PM

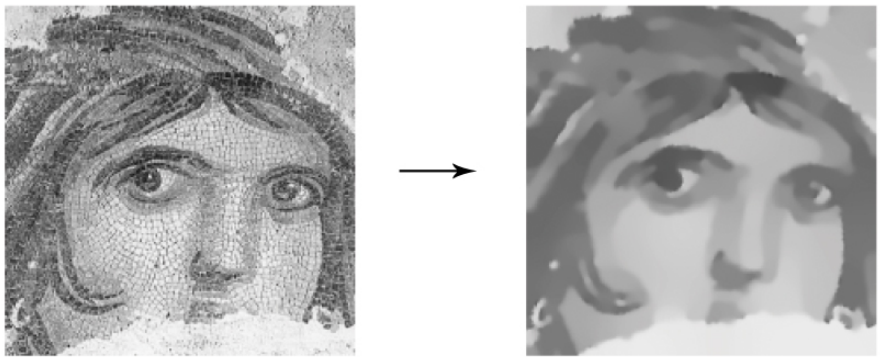

Figure 1: A sample filtering result obtained by the Perona-Malik model.

Overview

The purpose of this problem set is to familiarize you with nonlinear diffusion filtering. The main theory behind nonlinear diffusion filtering is to use nonlinear PDEs to create a scale space representation that consists of gradually simplified images where some image features such as edges are preserved or even enhanced. The assignment requires you to implement a number of nonlinear diffusion models and apply them to some sample images (Figure 1).

Problem 1.1

To smooth an image, implement a Perona-Malik (PM) type nonlinear diffusion model. Your program should take a grayscale image and a diffusivity model as inputs and produce a smoothed version of the input image as output. It should have the following structure:

1. Read the input image.
2. Decide on the diffusitivity model.
3. Set the parameters of the model.
    - contrast threshold: λ
    - scale parameter: σ
    - diffusion time: T
4. Perform smoothing.

You are provided a linear diffusion code. You can use this code as a skeleton and make the necessary changes to implement the PM model.

For your assignment, you need to implement the following diffusivity functions:

A. Perona-Malik diffusivity - Type 1 [1]:

$$g(|x|) = \exp\left(-|x|^2/\lambda^2\right) \tag{1}$$

B. Perona-Malik diffusivity - Type 2 [1]:

$$g(|x|) = \frac{1}{1+|x|^2/\lambda^2} \tag{2}$$

C. Charbonnier diffusivity [2]:

$$g(|x|) = \frac{1}{\sqrt{1+|x|^2/\lambda^2}} \tag{3}$$

Problem 1.2

Use your own implementation to address the following issues:

- Comparison of the results of linear and the nonlinear diffusion models.
- Effects of the parameters on the smoothing results (both for linear and nonlinear diffusion models)
- Changes in the mean intensity value, the variance of the intensities and total gradient magnitude throughout iterations.

Problem 1.3

Extend your implementation so that your program can smooth colored images as well.

For that, you can consider the following PDE defined for individual color channels:

$$\frac{\partial u^i}{\partial t} = \nabla \cdot \left(g\left(\sum_{k=1}^{3} |\nabla u_\sigma^k|\right) \nabla u^i \right) \tag{4}$$

where i denotes the color channel (R, G or B channels), $u_\sigma^i = G_\sigma * u^i$ represents a Gaussian-smoothed version of the ith color channel, and g is the diffusivity function.

Grading

The assignment will be graded out of 4: 0 *(no submission)*, 1 *(an attempt at a solution)*, 2 *(a partially correct solution)*, 3 *(a mostly correct solution)*, 4 *(a correct solution)*, 5 *(a particularly creative or insightful solution)*.

What to Hand In

You are required to submit all your code along with a report in HTML format. The codes you will submit should be well commented. Your report should be self-contained and should contain a brief overview of the problem, the details of your implemented solution and your comments about the experimental analysis on the aforementioned issues. Finally, prepare a ZIP file named `name-surname(s)-pa1.zip` containing

- `README.txt` - text file containing anything about the assignment that you want to tell but is not appropriate for the writeup webpage
- code/ - directory containing all your code for this assignment
- html/ - directory containing all your html report for this assignment, including images

The ZIP file will be submitted via email to `erkut@cs.hacettepe.edu.tr`.

Late policy

You may use up to five *extension* days (in total) over the course of the semester for the three programming assignments. Any additional unapproved late submission will be weighted by 0.5.

Academic Integrity

All work on assignments must be done individually unless stated otherwise. You are encouraged to discuss with your classmates about the given assignments, but these discussions should be carried out in an abstract way. That is, discussions related to a particular solution to a specific problem (either in actual code or in the pseudocode) will not be tolerated. In short, turning in someone else's work, in whole or in part, as your own will be considered as a violation of academic integrity. Please note that the former condition also holds for the material found on the web as everything on the web has been written by someone else.

References

1. P. Perona and J. Malik. Scale space and edge detection using anisotropic diffusion. IEEE Transactions on Pattern Analysis and Machine Intelligence, 12:629-639, 1990.
2. P. Charbonnier, L. Blanc-F¥eraud, G. Aubert, and M. Barlaud. Two deterministic half-quadratic regularization algorithms for computed imaging. In Proc. 1994 IEEE International Conference on Image Processing, volume 2, pages 168-172, Austin, TX, November 1994. IEEE Computer Society Press.