Computer Vision & Pattern Recognition – Spring Semester 2019

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Assignment 2

Date of submission: 22.05.2019 before the lecture.

If you have any questions, please send an email to the TAs. (firstname.lastname@usi.ch)

Exercise 1 (3 pts)

Considering the provided mri.png imag as reference, realize an **explicit** and a **semi-implicit** implementation of Perona & Malik non-linear (non-homogeneous) diffusion. Test the realized implementation using function:

$$c(x, y; t) = \frac{1}{1 + \left(\frac{||\nabla I(x,y;t)||}{K}\right)^2}$$

for determining the diffusion coefficients. Compare the two implemented schemes by visualizing the final filtered image obtained with:

(a) Explicit scheme, K = 0.01, 200 iterations and $\Delta t = \frac{1}{4}$

(b) Implicit scheme, K = 0.01, 10 iterations and $\Delta t = 5$

(c) Explicit scheme, K = 0.1, 200 iterations and $\Delta t = 5$

(d) Implicit scheme, K = 0.1, 200 iterations and $\Delta t = 5$

What happens at point (c)? And why?

Hint1: Use Additive Operator Splitting for implementing the semi-implicit scheme and the provided tridiag function for Thomas algorithm.

Hint2: For what concerns the explicit scheme you don't necessarily need to implement matrix A, you can just apply twice the first order central difference scheme for computing derivatives.

Hint3: To make the implementation easier for both schemes, you can consider the image "closed on itself" i.e. provided an $M \times N$ image whose pixels are sorted iterating over the columns, pixel (M, i) and $(1, i + 1)$ can be considered as neighbors for generic column i (the same is true for pixel (i, N) and $(i + 1, 1)$ if you order the pixels by rows).

Hint4: Avid any initial smoothing with gaussian kernel K_σ for simplicity (slide 18 lesson 5).

Exercise 2 (4 pts)

Imagine someone has written a note on your favorite photo. You would really like the original photo back. This is where image inpainting can be useful. In particular, we will focus on **total variation inpainting**, which is defined by the following functional

$$\min_{f \in F(\Omega)} \int_{\Omega\Omega_0} |f(x, y) - g(x, y)|^2 dxdy + \lambda \int_{\Omega} ||\nabla f(x, y)||_2 dxdy,$$

where the left part is the data term and the right one is the regularization term and Ω_0 represents the part of the photo covered by the text. In order to solve the functional, you have to:

(a) Compute the Euler-Lagrange equations of the TV-ipnainting functional

(b) Discretize the Euler-Lagrange equations with an explicit scheme

(c) Analyze the stability of the scheme. What can we say about the stability? And what about the choice of the time steps?

(d) Implmement the scheme and test it on the image attached to this homework.

Hint1: Remember that the function $||\dots||_2$ is not smooth around the origin, and you can replace it by its smooth relaxation as we have seen at the lecture.

Hint2: Notice that you have two integrals over two different areas. You can deal with Ω Ω_0 by using a membership function.

Hint3: Explore the functions spdiags in Matlab. In can simplify your implmentation greatly.

Hint4: Be careful about the choice of the time step. Not every time step will yield a stable solution.

Exercise 3 (4 pts)

In this exrcise we would like to deal with the problem of image segmentation using **geodesic active contours**. Let us model a grayscale image I as a surface

$$I : \Omega \to \mathbb{R}$$

Consider a closed convex planar curve C over the image I that contains the object we are interested to segment. Geodesic active contours describe the evolution of the curve C in terms of the evolution of the distance function ϕ from curve C with the following PDE

$$\phi_t = div\left(g(\nabla I)\frac{\nabla \phi}{||\nabla \phi||}\right)||\nabla \phi||.$$

If you consider as ϕ the signed Euclidean distance function ($||\phi|| = 1$), thus the previous equation reduces to the non-homogeneous diffusion process

$$\phi_t = div(g(\nabla I)\nabla \phi),$$

which can be rewritten as

$$\phi_t = \partial_x(g(\nabla I)\nabla \phi) + \partial_y(g(\nabla I)\nabla \phi).$$

Your task is to:

(a) Implement the geodesic active contours in Matlab with an AOS scheme and use it to segment some grayscale image of your choice.

(b) What can you say about efficiency of the AOS-based implementation? If it is slow, how would you eventually implement it more efficiently? (just explain in a few sentences)

Hint1: You might find Matlab functions bwdist and imfill useful.

Hint2: Don't forget about re-distancing of ϕ every few steps.

Hint3: The function $g()$ is the indicator function which was defined at the lecture.

Bonus Exercise (3 pts)

Study the paper Seam Carving for Content-Aware Image Resizing by Avidan etal.:

(a) Implement the algorithm and use it to extract to resize an image of your choice.

(b) Write technical report (as short as possible) describing how your implementation relates to what is described in the paper and showing your results.

Bonus Exercise (3 pts)

Study the paper Poisson image editing by Perez etal.:

(a) Implement the algorithm and use it to perform Seamless cloning (Section 3) to perform exchange similar to the one in Figure 4 in the paper.

(b) Write technical report (as short as possible) describing how your implementation relates to what is described in the paper and showing your results.