IT528 - Topics in Image Analysis(3-0-0-3)

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Course description

There are three aspects of a typical image processing solution: (a) Mathematical modeling as an optimization problem, (b) Closed form/iterative solution that converges to the optima and (c) Numerical schemes to obtain the optima. In this course we focus on PDE based or variational based problem modeling and numerical schemes to achieve the solution.

The course focusses on applications of Partial differential equations and Calculus of variations in image analysis/computer vision. Topics that will be treated in this course includes Diffusion equations, Variational energy minimization, their applications to Image denoising and segmentation, shape analysis (image inpainting, if time permits) and some numerical schemes needed to implement the above methods. The course will cover essentially a subset of topics covered in [1].

The students will be assumed to be familiar with basic concepts in Calculus, Linear algebra and Introductory Functional analysis.

List of topics

1. The heat equation and its applications to image processing [16, 14, 15, 20].
   (a) Linear heat equation.
   (b) Explicit/Implicit discretization schemes.
   (c) Perona Malik anisotropic diffusion.
   (d) The actual anisotropic diffusion (Weickert's approach).
2. Calculus of variations[8].
   (a) Euler-Lagrange equations, Gâteaux derivative.
   (b) Integration by parts, Adjoint of an operator.
   (c) Gradient descent.
   (d) Some examples/applications - Optical flow[9].
3. Image denoising
   (a) Tikhonov regularization[18].
   (b) Total variation regularization[17, 19, 4].
4. Image segmentation using active contours:
   (a) Curve evolution[11].

(b) KWT model[10].

(c) Level-set active contours[13].

(d) Geodesic active contours[3].

(e) Chan-Vese active contours[5].

(f) Fast & Global active contours[2, 6].

5. Shape analysis

   (a) Active shape models[7].

   (b) Geodesics in planar shape spaces[12].

Grading

The students will be required to understand/implement/present two papers, one each during the In-sem examinations. Students will be free to choose one paper related to their area of interest, while one will be given by the Course instructor based on topics covered in the course. There will also be regular assignments requiring coding and report writing.

The grading scheme is as follows:

1. Paper presentations: 15% + 15% = 30%.
2. Assignments: 40%
3. End-Sem Examination: 30%.

References

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[10] Michael Kass, Andrew P. Witkin, and Demetri Terzopoulos. Snakes: Active contour models. *International Journal of Computer Vision*, 1(4):321–331, 1988.

[11] Ron Kimmel. *Numerical Geometry of Images: Theory, Algorithms, and Applications*. SpringerVerlag, 2003.

[12] Eric Klassen, Anuj Srivastava, Washington Mio, and Shantanu H. Joshi. Analysis of planar shapes using geodesic paths on shape spaces. *IEEE Trans. Pattern Anal. Mach. Intell.*, 26(3):372–383, 2003.

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[14] K. W. Morton and D. F. Mayers. *Numerical Solution of Partial Differential Equations: An Introduction*. Cambridge University Press, 2005.

[15] P. Perona and J. Malik. Scale-space and edge detection using anisotropic diffusion. *IEEE Trans. Pattern Anal. Mach. Intell.*, 12:629–639, 1990.

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[19] C. R. Vogel and M. E. Oman. Iterative methods for total variation denoising. *SIAM J. Sci. Comput.*, 17(1):227–238, January 1996.

[20] Joachim Weickert. *Anisotropic Diffusion in Image Processing*. Teubner-Verlag, Stuttgart, Germany,, 1998.