EE 574
Image Analysis

Instructor: Assoc. Prof. Burak Acar

Course Description:

The course is mainly a mathematics based image analysis course. Special emphasis is given to variational techniques which lead to PDE based image processing algorithms, most of which are known as diffusion filters, and interface propagation techniques for which the emphasis will be implicit representation (level-set methods). Representation and properties of curves and surfaces, statistical (PCA/ICA) will be covered.

Prerequisite: EE 373 Signals and Systems
EE 475 Introduction to Image Processing (recommended)

Webpage: www.vavlab.ee.boun.edu.tr -> courses & links

Course Load and Grading:

This is a project & assignment based course. The students are required to join the liver segmentation challenge organized bu Dokuz Eylul University. The details of the challenge can be reached at https://eee.deu.edu.tr/moodle/mod/page/view.php?id=7872 . Important dates are as follows:

12.02.2018 : Register to the challenge using "Bogazici Univ – EE574" as your affiliation.
02.04.2018 : Submission of progress report (topic review inc.) (Grading: 20%)
27.04.2018 : Participation in the challenge (Grading: 30%) – In case you will not be able to participate in the challenge, you must inform the instructor at least a month ago for an alternative arrangement
15.05.2018: Submission of final report (Grading: 30%)
16.05.2018: Project presentations (Grading: 20%)

The project report will be in IEEE Transactions paper format (12 pages max, 2 columns). The content and organization of your report should be just like a full paper, ie. including introduction, method (a presentation of main approaches in literature with a taxonomy, for the review paper assignment), evaluation (may be skipped for the review paper assignment), discussion (must discuss the pros/cons of different approaches for the review paper) and conclusion sections. You can find templates and guidelines at the course web page. You are also required to give a presentation about your project at the end of the semester. The presentation is required to be in a conference presentation format (15 min + 5 min for questions).

Textbook: No textbook. The course material is composed of the following sources

1. Aubert & Kornprobst, *Mathematical Problems in Image Processing,* Springer, 2000
2. Sethian, *Level-Set Methods and Fast Marching Methods,* Cambridge University Press, 1999
3. Sapiro, *Geometric Partial Differential Equations and Image Analysis,* Cambridge University Press
4. Osher & Fedkiw, *Level-Set Methods and Dynamic Implicit Surfaces,* Springer, 2003
5. Osher & Paragios (Edt.), *Geometric Level-Set Methods in Imaging, Vision and Graphics,* Springer, 2003
6. Do Carmo, *Differential geometry of curves and surfaces, Prentice-Hall, 1976*
7. Van Brunt, *The Calculus of Variations,* Springer, 2004
8. Paragios et al.,*Handbook of Mathematical Models in Computer Vision*, Springer
9. Dr. Younes's lecture notes on Geometry of Shapes and Image Analysis

Course Outline:

1. **Image Spaces:** Function spaces, Norms on functions, L2 spaces, Hilbert structure, Lp norms, Bounded-Variation functions
2. **Variational Image Enhancement:** Euler-Lagrange eqn., L2-norm and BV-norm energy minimization, Solving the minimization problem, Custom built potential functions, Designing a potential function, Popular diffusion filters, Diffusion vs Oriented Laplacian
3. **Variational Image Segmentation**: Curves, Variational formulation, Implicit Curves (Level-Sets), Curve evolution, Discretization (Upwinding), Fast marching, Surfaces, Surface evolution
4. **Statistical Models:** PCA, ASMs, Explicit/Implicit models in segmentation
5. **Graph Based Segmentation**: Spectral graph analysis (Normalized cuts, Laplacian Eigenmaps), MRFs, MinCut-MaxFlow

Compulsory Reading List:

1. Variational Image Enhancement
    - Perona, P., & Malik, J. (1990). *Scale-Space And Edge Detection Using Anisotropic Diffusion*. PAMI 12(7), 629 - 639.
    - Weickert, J. (1997). *A Review Of Nonlinear Diffusion Filtering.* Scale Space Theory In Computer Vision, Vol. 1252, Pp. 3-28. Springer, Berlin.
    - Weickert, *Coherence Enhancing Diffusion Filtering,* Int. J. Computer Vision, 31/2-3, 111-127, 1999
    - Kimmel et al., *Images as embedded maps and minimal surfaces: Movies, color, texture, and volumetric medical images*, Int. J. Computer Vision, 39/2, 2000
    - Keeling Stephen L , *Total variation based convex filters for medical imaging*. Applied Mathematics and Computation (2003 Jan 1) 139 (1): 101-119.
    - Tschumperle et al., *Vector-Valued Image Regularization with PDEs: A Common Framework for Different Applications*, PAMI 27/4, 2005
2. Variational Image Segmentation
    - Kaas, M. (1987). *Snakes - Active Contour Models*. ICCV'87, pp. 259-268.
    - Williams, D.J., & Shah, M. (1992). *A Fast Algorithm For Active Contours And Curvature Estimation*. CVGIP: Image Understanding 55(1), 14-26
    - Malladi, R., Sethian, J.A., & Vemuri, B.C. (1995). *Shape Modeling With Front Propagation: A Level Set Approach*. PAMI 17(2), 158.
    - Caselles, V., Kimmel, R., & Sapiro, G. (1997). *Geodesic Active Contours*. International Journal Of Computer Vision 22(1), 61.
    - Siddiqi, K., Lauziere, Y.B., Tannenbaum, A., & Zucker, S.W. (1998). *Area And Length Minimizing Flows For Shape Segmentation*. Image Processing, IEEE Transactions On 7(3), 433-443.
    - Chan, T. F., & Vese, L. A. (2001). Active contours without edges. IEEE Transactions on Image Processing, 10(2), 266-277
    - Paragios, N., Mellina-Gottardo, O., & Ramesh, V. (2004). *Gradient Vector Flow Fast Geometric Active Contours*. PAMI 26(3), 402-407.
    - Rieger et al., *On curvature estimation of ISO surfaces in 3D gray-value images and the computation of shape descriptors*, PAMI 26/8, 2004

- Monga O., et al. *Using Partial Derivatives of 3D Images to Extract Typical Surface Features*, Computer Vision and Image Understanding, 61/2, 171-189, 1995
- Suri, J.S., Liu, K.C., Singh, S., Laxminarayan, S.N., Zeng, X.L., & Reden, L. (2002). *Shape Recovery Algorithms Using Level Sets In 2-D/3-D Medical Imagery: A State-Of-The-Art Review*. IEEE Transactions On Information Technology In Biomedicine 6(1), 8-28.

3. Graph Based Segmentation
    - Shi JB, Malik J, *Normalized cuts and image segmentation*, IEEE PAMI 22/8, 2000
    - Boykov and Funka-Lea, *Graph cuts and efficient N-D segmentation*, IJCV 70/2, 2006
    - Boykov and Kolmogorov, *An experimental comparison of mincut/maxflow algorithms for energy minimization in vision*, IEEE PAMI, 26/9, 2004
    - Wang, S., & Siskind, J. (2003). *Image Segmentation With Ratio Cut*. PAMI 25(6), 675- 690-674.
    - Kang, L., Xiaodong, W., Chen, D.Z., & Sonka, M. (2006). *Optimal Surface Segmentation In Volumetric Images-A Graph-Theoretic Approach,* PAMI 28(1), 119
    - Grady, L. (2006). *Random Walks For Image Segmentation*. PAMI 28(11), 1768.
4. Markov Random Fields
    - Li S.Z., Markov Random Field Models in Computer Vision, ECCV
    - Wang Chaohui, Komodakis Nikos, Paragios Nikos (2013). *Markov Random Field modeling, inference & learning in computer vision & image understanding: A survey*. Computer Vision and Image Understanding (2013 Jan 1) 117 (11): 1610-1627.
    - Li S. Modeling Image Analysis Problems Using Markov Random Fields
5. Statistical Methods
    - Cootes, T. (2001*). Statistical Models of Appearance for Computer Vision*.
    - Leventon, M.E., Grimson, W.E.L., Faugeras, O., 2000. *Statistical shape influence in geodesic active contours*. In: Proc. IEEE CVPR, vol. 1.
    - Tobias Heimann, Hans-Peter Meinzer, *Statistical shape models for 3D medical image segmentation: A review*, Medical Image Analysis, Volume 13, Issue 4, August 2009
    - Cremers D. et al, *A Review of Statistical Approaches to Level Set Segmentation: Integrating Color, Texture, Motion and Shape,* International Journal of Computer Vision 72(2), 195–215, 2007
    - Fredembach, C., Schroder, M., & Susstrunk, S. (2004). *Eigenregions For Image Classification*. PAMI 26(12), 1645-1649.