

UNIVERSITAT POLITÈCNICA DE CATALUNYA

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**MULTIRESOLUTION IMAGE
SEGMENTATION BASED ON
COMPOUND RANDOM FIELDS:
APPLICATION TO IMAGE CODING**

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REFERENCES

- [0] F. Marqués, *Procesado de imágenes para la detección de contornos en ecocardiogramas de tipo B*, Projecte Fi de Carrera, U.P.C., Barcelona, 1988
- [1] R. M. Haralick, L. G. Shapiro, "Image segmentation techniques," *Computer Vision, Graphics, and Image Processing*, vol. 29, pp. 100-132, January 1985.
- [2] M. Bertero, T. A. Poggio, V. Torre, "Ill-posed problems in early vision," *Proceedings of the IEEE*, vol. 76, pp. 869-887, 1988.
- [3] D. Marr, *Vision*, W. H. Freeman, New York, 1982.
- [4] B. S. Lipkin, "Introduction: Psychopictorics," in *Picture Processing and Psychopictorics*, B. S. Lipkin and A. Rosenfeld, Academic Press, New York, 1970.
- [5] M. D. Levine, *Vision in man and machine*, New York, McGraw-Hill, 1985.
- [6] D. H. Ballard, C. M. Brown, *Computer vision*, Prentice Hall, New Jersey, 1982.
- [7] R. Wilson and M. Spann, *Image segmentation and uncertainty*, Research Studies Press Ltd., Letchmore, Hertfordshire, England, 1988.
- [8] R. C. Gonzalez, P. Wintz, *Digital image processing*, Addison-Wesley, Massachusetts, 1987.
- [9] F. M. Wahl, *Digital image signal processing*, Artech House, Boston, 1987.
- [10] D. Vernon, *Machine vision. Automated visual inspection and robot vision*, Prentice Hall International (UK) Ltd, 1991.
- [11] L. G. Roberts, "Machine perception of three-dimensional solids," in *Optical and Electro-Optical Information Processing*, J. T. Tippett et al., MIT Press, Cambridge, MA, pp. 159-197.
- [12] W. K. Pratt, *Digital image processing*, Wiley-Interscience, New York, 1991.

- [13] J. M. S. Prewitt, "Object enhancement and extraction," in *Picture processing and psychopictorics*, B. S. Lipkin and A. Rosenfeld, academic Press, New York, 1970.
- [14] J. Serra, *Image analysis and mathematical morphology*, Academic Press, London, 1982.
- [15] S. Beucher, *Segmentation d'images et morphologie mathématique*, PhD Thesis, Paris School of Mines, Paris, June 1990.
- [16] D. Marr and E. Hildreth, "Theory of edge detection," *Proc. Roy. Soc. London*, B207, pp. 187-217, 1980.
- [17] R. Kirch, "Computer determination of the constituent structure of biomedical images," *Computers and Biomedical Research*, vol. 4, pp. 315-328, 1971.
- [18] W. Frei and C. Chen, "Fast boundary detection: A generalization and a new algorithm," *IEEE Trans. Computers*, vol. 26, pp 988-998, 1977.
- [19] M. F. Hueckel, "An operator which locates edges in digitized pictures," *Journal Assoc. Comput. Mach.*, vol. 20, pp. 634-637, 1973.
- [20] V. S. Nalwa and T. O. Binford, "On detecting edges," *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 6, pp.699-714, 1986.
- [21] Y. Yakimovsky, "Boundary and object detection in real world images," *Journal of the Assoc. Computing Machinery*, vol. 23, pp. 599-618, 1976.
- [22] R. J. Schalkoff, *Digital image processing and computer Vision*, John Wiley & Sons, New York, 1989.
- [23] J. J. Gerbrands, *Segmentation of noisy images*, PhD Thesis, Delft University of Technology, Delft, 1988.
- [24] J. L. Muerle and D. C. Allen, "Experimental evaluation of techniques for automatic segmentation of objects in a complex scene," in *Pictorial Pattern Recognition*, G. C. Cheng et al., Eds., pp. 3-13, Thompson, Washington, 1968.
- [25] A. Rosenfeld and A. C. Kak, *Digital picture processing*, vol. 2, Academic Press, Orlando, Florida, 1982.

- [27] J. M. Loscher, *Codage d'images à haute compression basé sur un modèle contour-texture*, PhD Thesis, Ecole Polytechnique Fédérale de Lausanne, Lausanne, 1983.
- [28] T. Pavlidis, *Structural pattern recognition*, Springer, New York 1977.
- [29] S. L. Horowitz and T. Pavlidis, "Picture segmentation by a directed split-and-merge procedure," in *Proc. 2nd Int. Joint Conf. on Pattern Recognition*, pp. 424-433, 1974.
- [30] K. S. Fu, R. C. Gonzalez and C. S. G. Lee, *Robotics: Control, sensing, vision and intelligence*, McGraw-Hill, New York, 1987.
- [31] S. L. Horowitz and T. Pavlidis, "Picture segmentation by a tree traversal algorithm," *Journal of the Assoc. Computing Machinery*, vol. 23, pp. 368-388, 1976.
- [32] Y. Fukada, "Spatial clustering procedures for region analysis," *Pattern Recognition*, vol. 12, pp. 395-402, 1980.
- [33] R. Leonardi, *Segmentation adaptative pour le codage d'images*, PhD Thesis, Ecole Polytechnique Fédérale de Lausanne, Lausanne, 1987.
- [34] P. C. Chen and T. Pavlidis, "Image segmentation as an estimation problem," *Computer Graphics and Image Processing*, vol. 12, pp. 153-172, 1980.
- [35] P. J. Burt, T. H. Hong and A. Rosenfeld, "Segmentation and estimation of image region properties through cooperative hierarchical computation," *IEEE Transactions on Systems, Man and Cybernetics*, vol. 11, pp. 802-809, 1981.
- [36] S. Kasif and A. Rosenfeld, "Pyramid linking is a special case of ISODATA," *IEEE Trans. on Systems, Man and Cybernetics*, vol. 13, pp. 84-85, 1983.
- [37] L. A. Zadeh, "Fuzzy sets," *Information Control*, vol. 8, pp. 338-353, 1965.
- [38] J. C. Bezdek, *Pattern recognition with fuzzy objective function algorithms*, Plenum, New York, 1981.
- [39] B. Jähne, *Digital image processing*, Springer-Verlag, Berlin, 1991.
- [40] M. Pietikäinen and A. Rosenfeld, "Image segmentation by texture using pyramid node linking," *IEEE Transactions on Systems, Man and Cybernetics*, vol. 11, pp. 822-825, 1981.

- [40] C. Horne, *Unsupervised image segmentation*, PhD Thesis, Ecole Polytechnique Fédérale de Lausanne, Lausanne, 1990.
- [41] A. Papoulis, *Probability, random variables, and stochastic processes*, McGraw-Hill, New York, 1965.
- [42] A. K. Jain, "Advances in mathematical models for image processing," *Proc. of the IEEE*, vol. 69, pp. 502-528, 1981.
- [43] F. C. Jeng, J. W. Woods, "Inhomogeneous Gaussian image models for image estimation and restoration," *IEEE Trans. Acoust. Speech, Signal Processing*, vol. 36, pp. 1305-1312, 1988.
- [44] H. E. Knutsson, R. Wilson, G. H. Granlund, "Anisotropic nonstationary image estimation and its applications: Part I.- Restoration of noisy images," *IEEE Trans. Comm.*, vol. 31, pp. 388-197, 1983.
- [45] H. Derin, P. Kelly, "Discrete-index Markov-type random processes", *Proceedings IEEE*, vol. 77, pp. 1485-1510, 1989.
- [46] J. W. Woods, "Two-dimensional discrete Markovian fields", *IEEE Trans. Inform. Theory*, vol. 18, pp. 232-240, 1972.
- [47] K. Abend, T. J. Harley, L. N. Kanal, "Classification of binary random patterns," *IEEE Trans. Inform. Theory*, vol. 11, pp. 538-544, 1965.
- [48] J. Besag, "Spatial interaction and the statistical analysis of lattice systems (with discussion)," *J. Royal Statisc. Soc.*, series B, vol. 34, pp. 75-83, 1972.
- [49] R. L. Kashyap, "Image models," in *Handbook of pattern recognition and image processing*, T. Y. Young and K. S. Fu eds., Academic Press, New York, 1986.
- [50] R. L. Kashyap, R. Chellappa, "Estimation and choice of neighbors in spatial-interaction models of images," *IEEE Trans. Inform. Theory*, vol. 29, pp. 60-72, 1983.
- [51] G. R. Cross, A. K. Jain, "Markov random field texture models," *IEEE Trans. Pattern Analysis and Machine Inteligence*, vol. 5, pp.25-39, 1983.
- [52] R. Chellappa, S. Chatterjee, "Classification of textures using Gaussian Markov random fields," *IEEE Trans. Acoust. Speech, Signal Processing*, vol. 33, pp. 959-963, 1985.

- [53] F. Cohen, *Parallel adaptive hierarchical segmentation of textured images using noncausal Markovian fields*, PhD Thesis, Brown University, August 1983.
- [54] F. Cohen, "Adaptive hierarchical algorithm for accurate image segmentation," *Proc. of the Int. Conf. on Acoust. Speech, Signal Processing-85*, pp. 24.3.1-24.3.4, Tampa, 1985.
- [55] H. Derin, H. Elliot, R. Cristi, D. Geman, "Bayes smoothing algorithms for segmentation of images modeled by Markov random fields," *Proc. of the Int. Conf. on Acoust. Speech, Signal Processing-84*, pp. 32.6.1-32.6.4, San Diego, 1984.
- [56] S. Geman D. Geman, "Stochastic relaxation, Gibbs distribution, and the Bayesian restoration of images," *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 6, pp.721-741, 1984.
- [57] F. C. Jeng, J. W. Woods, "Compound Gauss-Markov random fields for image estimation," *IEEE Trans. on Signal Processing*, vol. 39, pp. 683-697, 1991.
- [58] G. Demoment, "Image reconstruction and restoration: overview of common estimation structures and problems," *IEEE Trans. Acoust. Speech, Signal Processing*, vol. 37, pp. 2024-2036, 1989.
- [59] H. Elliot, H. Derin, R. Cristi, D. Geman, "Application of the Gibbs distribution to image segmentation," *Proc. of the Int. Conf. on Acoust. Speech, Signal Processing-84*, pp. 32.5.1-32.5.4, San Diego, 1984.
- [60] H. Derin , W. Cole, "Segmentation of textured images using Gibbs random fields," *Computer Vision, Graphics and Image Processing*, vol. 35, pp. 72-98, 1986.
- [61] H. Derin , H. Elliot, "Modeling and segmentation of noisy and textured images using Gibbs random fields," *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 9, pp.39-55, 1987.
- [62] E. Aarts, J. Korst, *Simulated annealing and Boltzmann machines*, John Wiley & Sons Ltd., Chichester, 1989.

- [63] S. Lakshmanan, H. Derin, "Simultaneous parameter estimation and segmentation of Gibbs random fields using simulated annealing," *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 11, pp.799-813, 1989.
- [64] R. Hu, M. M. Fahmy, "Texture segmentation based on a hierarchical Markov random field model," *Signal Processing*, vol.26, pp. 285-305, 1992.
- [65] R. Mester, U. Franke, "Statistical model based image segmentation using region growing, contour relaxation and classification" *Proc. of the SPIE Conference on Visual Comm. and Image Proc. '88*, pp. 616-624, Cambridge, USA, 1988.
- [66] F. Marqués, A. Gasull, T. R. Reed, M. Kunt, "Coding-oriented segmentation based on Gibbs-Markov random fields and human visual system knowledge," *Proc. of the Int. Conf. on Acoust. Speech, Signal Processing-91*, pp. 2749-2752, Toronto, Canada, 1991.
- [67] F. S. Cohen, D. B. Cooper, "Simple parallel hierarchical and relaxation algorithms for segmenting noncausal markovian random fields," *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 9, pp.195-219, 1987.
- [68] B. S. Manjunath, R. Chellappa, "Unsupervised texture segmentation using Markov random field models," *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 13, pp.478-482, 1991.
- [69] T. N. Pappas, N. S. Jayant, "An adaptive clustering algorithm for image segmentation," *Proc. of the Int. Conf. on Computer Vision*, pp. 310-315, USA, 1988.
- [70] C. Bouman, B. Liu, "Multiple resolution segmentation of textured images," *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 13, pp. 99-113, 1991.
- [71] C. Bouman, M. Shapiro, "Multiespectral image segmentation using a multiscale model," *Proc. of the Int. Conf. on Acoust. Speech, Signal Processing-92*, pp. III.565-III.568, San Francisco, USA, 1992.
- [72] A. Dempster, N. Laird, D. Rubin, "Maximum likelihood from incomplete data via the EM algorithm," *Journal Royal Statis. Society B*, vol. 39, pp. 1-38, 1977.
- [73] P. Salembier, M. Kunt, "Size-sensitive multiresolution decomposition of images with rank order based filters," *Signal Processing*, vol. 27, pp. 205-241, 1992.

- [74] P. J. Burt and E. Adelson, "The Laplacian Pyramid as a Compact Image Code," *IEEE Trans. on Comm.*, vol. 31, pp. 532-540, 1983.
- [75] A. V. Openheim, A. S. Willsky, I. T. Young, *Signals and systems*, Prentice-Hall International, Inc. London, 1983.
- [76] F. Marqués, J. Cunillera, A. Gasull, "Hierarchical segmentation using compound Gauss-Markov random fields," *Proc. of the Int. Conf. on Acoust. Speech, Signal Processing-92*, pp. III.53-III.56, San Francisco, USA, 1992.
- [77] J. Serra, *Image analysis and mathematical morphology, vol. II: Theoretical advances*, Academic Press, London, 1988.
- [78] L. Vincent, *Algorithmes morphologiques à base de files d'attente et de lacets. Extension aux graphes*, PhD Thesis, École de Mines, Paris, 1990.
- [79] F. Meyer, "Automatic screening of cytological specimens," *Computer Vision, Graphics, and Image Processing*, vol. 35, pp. 356-369, 1986.
- [80] G. Matheron, "Filters and lattices," in *Image Analysis and Mathematical Morphology, vol. II: Theoretical advances*, J. Serra, Academic Press, London, 1988.
- [81] P. Salembier, "Comparison of some morphological segmentation algorithms based on contrast enhancement - Application to defect detection -," *Proc. of EUSIPCO'90 Conf., Signal Processing V: Theories and Applications*, pp. 833-836, Barcelona, Spain, 1990.
- [82] N.S. Jayant and Peter Noll. *Digital coding of waveforms*. Prentice-Hall, inc. Englewood Cliffs, New Jersey 1984.
- [83] A. Gersho, R. M. Gray, *Vector quantization and signal compression*, Kluwer Academic Pub., Boston 1992.
- [84] M. Kunt, A. Ikonomopoulos and M. Kocher. "Second generation image coding techniques," *Proceedings of the IEEE*, vol. 73, pp. 549-575, April 1985.
- [85] B. Ramamurthi and A. Gersho, "Classified vector quantization of images," *IEEE Trans. Commun.*, vol. 34, pp. 1105-1115, Nov. 1986.
- [86] T. Ebrahimi, *Perceptually derived localized linear operators: Application to image sequence compression*, PhD Thesis, Ecole Polytechnique Fédérale de Lausanne, Lausanne, 1992.

- [87] H. A. Peterson, *Image segmentation using human visual system properties with applications in image compression*, PhD Thesis, School of Electrical Engineering, Purdue University, West Lafayette, Indiana, 1990.
- [88] H. Freeman, "On the encoding of arbitrary geometric configurations," *IRE Trans. Electron. Comput.*, vol 10, pp. 260-268, June 1961.
- [89] C. H. Teh, R. T. Chin, "On the detection of dominant points on digital curves," *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 11, pp. 859-872, 1989.
- [90] M. Eden, M. Kocher, "On the performance of contour coding algorithm in the context of image coding. Part I: Contour segment coding," *Signal Processing*, vol. 8, pp. 381-386, 1985.
- [91] D. Huffman, "A method for the construction of minimum redundancy codes," *Proc. IRE*, pp. 1098-1101, 1952.
- [92] S. Carlsson, "Sketch based coding of grey level images," *Signal Processing*, vol. 15, pp. 57-83, 1988.
- [93] F. Meyer, "Skeletons and perceptual graph", *Signal Processing*, vol. 16, pp. 335-363, 1989.
- [94] P. Elias, "A method for the construction of minimum redundancy codes,' *IRE Trans. on Information Theory*, vol. 2, pp. 16-33, 1955.