Special Issue Guest Editorial

Image Restoration and Reconstruction

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The problem of image restoration refers to finding an estimate of the ideal image from its blurred and noisy rendition. On the other hand, image reconstruction refers to the problem of finding an estimate of the ideal image from possibly incomplete and noisy data, which is not necessarily in the form of an image. Although the applications of image restoration and reconstruction differ in nature, these two problems share a common mathematical ground in that they are both ill-posed inverse problems. Since solution strategies for both problems are heavily based on this common property, we discuss both problems in this special issue.

Early applications of digital image restoration have been mostly in space imagery, which took place in large institutions and government laboratories. Today, however, digital image restoration attracts wider interest and has a much broader spectrum of applications ranging from consumer/commercial imaging to forensic science. This is due mainly to the availability of powerful workstations and image input-output devices at affordable costs. Early applications of image reconstruction have been in astronomy, where images have been reconstructed from their projections, or Fourier moduli. Over the years, image reconstruction has found a growing number of applications in a multitude of fields such as medicine, astronomy, remote sensing, geophysics, and nondestructive evaluation. In the last decade, tomographic image reconstruction has revolutionized the field of medicine. The recent interest in image reconstruction is due mainly to the introduction of new imaging modalities, such as cone-beam tomography, magnetic resonance (MR) imaging, positron emission tomography (PET), and single photon emission computerized tomography (SPECT), and their high potential in medical diagnosis.

The objective of this special issue is to report the recent progress in the fields of image restoration and reconstruction. The first part of the issue features papers on digital image restoration and estimation. These papers discuss present problems of interest in digital image restoration and estimation, which are (i) modeling of image degradations, (ii) identification of degradation and image models from a given degraded image, (iii) robust, regularized image restoration, (iv) adaptive filtering of noisy images, and (v) filtering color images. Papers on image reconstruction are featured next. These papers are chosen to cover (i) image reconstruction from bispectrum, (ii) image reconstruction from spatial and/or Fourier magnitude, (iii) 2-D and 3-D tomographic image reconstruction, (iv) ultrasound imaging, and (v) reduction of artifacts in PET, MR, and ultrasound imaging. We briefly introduce each paper in the following.

The first seven papers address the restoration of images degraded by blur and additive noise. The paper by Sezan and Tekalp provides a tutorial survey of image restoration, with an emphasis on recent developments and research results in the field. Modeling of blur degradations due to a number of sources (e.g., out-of-focus lenses, moving objects, camera and film characteristics) is discussed by Lee. A review of several image and blur identification methods, within a unifying maximum likelihood framework, is presented by Lagendijk, Tekalp, and Biemond. Lay and Katsaggelos present an expectation-maximization (EM) algorithm that is formulated entirely in the spatial frequency domain for the maximum likelihood image and blur identification problem. Reeves and Mersereau propose using the generalized cross-validation principle in finding the optimum constraint operator and the regularization parameter in constrained least squares image restoration. Zervakis and Venetsanopoulos present robust M-estimators that are optimum in the least squares sense for restoring images recorded by nonlinear sensors in the presence of long-tailed noise processes. A stopping rule for linear iterative image restoration methods is proposed in the paper by Sullivan and Katsaggelos. The next three papers address the problem of image estimation in the absence of blur. Moloney and Jernigan develop an adaptive minimum mean square error (MMSE) estimator for filtering images degraded by multiplicative noise. Filtering images degraded by additive noise is considered in the paper by Mahesh, Song, and Pearlman, where the minimum-error minimum-correlation (MEMC) principle is introduced and used to develop an adaptive image estimator. Pitas considers the extension of the concept of ordering and order statistical filtering to multichannel imagery and provides a statistical analysis of marginal order filtering for color images.

The next paper, by Dianat and Raghuveer, discusses reconstruction of images from their bispectra. Reconstructing an image from its modulus and/or that of its Fourier transform (the phase recovery problem) is considered in the next paper. Herman and Ro show that a number of well-known reconstruction algorithms such as the Gerchberg-Saxton and the error reduction method of Fienup can be formulated in the general framework of iterative data refinement (IDR) methods, and they develop an algorithm in this framework for reconstructing T2-weighted MR images with improved resolution. The following two papers address the tomographic image reconstruction problem. Smith provides an in-depth and up-to-date tutorial review of 3-D tomographic image reconstruction from cone-beam data. Prince and Willsky develop a projection-space method for reconstructing tomographic images from angularly view limited and possibly noisy projection data. Echo image reconstruction from data collected by both physical and synthesized arrays is considered in the paper by Soumekh. Image reconstruction with improved signal-to-noise ratio and reduced artifacts in MR and ultrasound imaging is discussed in the paper by Haacke, Liang, and Boada, where reconstruction methods based on model constraints and linear prediction theory are developed. Abidi and Davis develop a postprocessing technique to remove streak artifacts in PET imaging.

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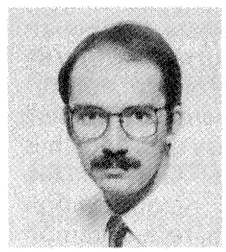
M. Ibrahim Sezan was born in Istanbul in 1958. He received BS degrees in electrical engineering and mathematics from Boğaziçi University, Istanbul, in 1980 with highest honors, an MS degree in physics from Stevens Institute of Technology, Hoboken, New Jersey, in 1982, and MS and Ph.D. degrees in electrical, computer, and systems engineering from Rensselaer Polytechnic Institute, Troy, New York, in 1983 and 1984, respectively. Since 1984, he has been with Eastman Kodak Company in Rochester, where he is presently a senior research scientist in the Imaging Science Laboratory of the Photographic Research Laboratories. His responsibilities include conducting and coordinating research in image restoration. He was an adjunct assistant professor of mathematics at the University of Rochester in the spring of 1987, and in the fall of 1987, he was a visiting assistant professor of electrical engineering at Rensselaer Polytechnic Institute. Currently, he is an adjunct assistant professor in the Electrical and Computer Engineering Department at Syracuse University. His current research interests include image restoration and reconstruction, image data compression, medical imaging, and neural networks. Dr. Sezan was corecipient of the A. B. Du Mont award at Rensselaer Polytechnic Institute in 1984. He is an Associate Editor of the *IEEE Transactions on Medical Imaging* and is vice-president of the Rochester Chapter of the IEEE Acoustics, Speech, and Signal Processing Society. He contributed to the books *Image Recovery: Theory and Application* (Academic Press, 1987), *Handbook of Signal Processing* (Marcel Dekker, 1988), and *Digital Image Restoration* (Springer-Verlag, forthcoming in 1990). Dr. Sezan is a member of the IEEE, SPIE, and Sigma Xi.



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