BOOK REVIEWS

Fundamentals of Electronic Imaging Systems

W. F. Schreiber, 304 pages, 2nd edition, ISBN 0-3875-3272-2, Springer-Verlag, 175 Fifth Avenue, New York, NY 10010 (1991) $54 softcover.

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This is the second edition of a book first published in 1986. The second edition is essentially the contents of the first edition plus additional chapters covering color theory, current television systems, and the development of HDTV worldwide. This book will thrill system designers and perhaps leave some academicians with mixed feelings. Covering most areas of a generalized image processing system such as optics, visual perception, sampling theory, compression, color, and video display, this book serves as a helpful handbook for the imaging systems designer. The book covers some fundamentals and describes the principles behind many practical, real-world systems.

Chapter 1 describes, in general terms, the elements of a generalized image processing system, including the optical system, the camera, source and channel encoding and decoding, and the display. Attention is given to the perception of image quality, including aspects of motion flicker perception. Chapter 2 covers the areas of photometry and radiometry, a short tutorial on Fourier optics and linear systems theory, and the statistics behind the quantum nature of light and how it relates to the ultimate sensitivity of image capture devices. Chapter 3 deals with the perception of images and is an account of most of the major practical findings of the vision research field. Chapter 4 introduces the concepts of sampling, interpolation, and quantization. Chapter 5 deals with image compression by giving a short tutorial of basic information and theoretic concepts and then citing some of the most popular techniques in use in present-day imaging systems. Coding techniques for both natural imagery and graphics are discussed. Chapter 6 is a comprehensive historical review of the graphic sciences including type composition, plate making, and the halftone process. Chapter 7 is new to the second edition and covers color theory, including numerical colorimetry, color spaces, color representation in analog and digital systems, and experimental results in color perception. Chapter 8 is also new to the second edition and discusses television basics, NTSC, channel considerations, specialized video signal processing techniques, and many applications. An appendix new to the second edition discusses the state of HDTV development worldwide, including compatibility issues and the various proposed schemes.

What is perhaps most refreshing about this book is the applied nature of the presentation of the material; it was obviously written based on the many years of practical system development work Professor Schreiber and his students at the Massachusetts Institute of Technology have done. Although other texts exist on more specific aspects of the imaging sciences, it is the style of presentation that really separates this book from other more popular texts used in undergraduate and graduate courses on imaging. Many facts and rules of thumb are presented in an argumentative way, as if the reader were having an office conversation with Prof. Schreiber. All too often students of imaging science, either by major or elective course, study strictly the fundamentals without application. This book, although not covering the most sophisticated concepts and techniques, is in fact a high-level text, appropriate for a graduate course taken after a student has been exposed to all of the imaging basics in separate courses. This text should go a long way in helping a recent graduate enter the real world of imaging with his feet running.

For the practicing imaging systems designer, the many rules of thumb and arguments presented in this book can be quite helpful in designing a modern imaging system. For instance, in Chapter 4 the author recommends that unless a quantized image is to be further coded by some statistical method, the addition of Roberts's noise clearly improves image quality without increasing channel capacity. In Chapter 8 he notes that "Most observers believe that HDTV requires displays of 30 inches or more, which makes CRTs impractical for many viewing situations. If this is true, and no economical, relatively thin display device is developed within the next few years, the growth of HDTV may be inhibited."

Other helpful insights mentioned in the book are of a philosophical nature. In Chapter 5 the author discusses the importance of quoting the effect of sampling density and viewing conditions on the efficiency of a compression algorithm; quotation of a bit rate without this qualification is incomplete. In Chapter 6 he states that many printers and photo editors tend to ignore the fact that many images used in the prepress environment tend to be intermediates, to be further reproduced: "The attempt to get best eyeball quality at every stage of a picture reproduction system invariably reduces the quality of the final result."

What may be disappointing to some academicians is that the author teases the reader with many insights and creative analogies, but too often does not explain the why behind them. For example, in Chapter 2 the author derives a relation between the image illuminance and the object luminance in terms of the lens *f*/number and magnification m; a higher *f*/number or magnification would decrease the image illuminance. He cites that "In accordance with the second law of thermodynamics, [and] since f cannot be much less than unity for geometrical reasons, the image illuminance is always less than the object luminance." This relationship makes intuitive sense to me, but I would have been fascinated with a description of this in terms of the second law of thermodynamics. Secondly, I would have appreciated a deeper explanation regarding the geometrical limit of the *f*/number.

Overall, I believe the book is a great service to the field. Although the fundamentals are covered in more detail in perhaps a dozen other texts, *Fundamentals of Electronic Imaging Systems* represents an account of the most readily applied results and findings developed within the field of imaging science during the past 100 years. Schreiber holds great respect for traditional image makers who have highly perfected the imaging craft, and he believes that our inability as scientists to model exactly the perceived characteristics desired by the "experts" should not be a stumbling block to imaging systems design. The right balance of theory and empiricism will always be a prudent quality in designing a modern imaging system.

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Iterative Identification and Restoration of Images

Reginald L. Lagendijk and Jan Biemond, 224 pages, ISBN 0-7923-9097-0, Kluwer Academic Publishers, 101 Philip Drive, Norwell, MA 02061 (1991) $67.50 hardbound.

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This monograph on iterative image identification and restoration contains the doctoral dissertation written by the principal author. Before I summarize its contents, let me first introduce the problem addressed by the book. Image restoration refers to the problem of finding an estimate of an image from its blurred and noisy rendition. Blur, in most cases, may be due to relative motion between the object and the imaging system, and/or due to out-of-focus lenses in the imaging system. Sensor noise and quantization noise are among the most common types of noise in digital images. Image restoration, in general, is a mathematically ill-posed, inverse problem. In other words, an exact solution may not exist, and even if an approximate solution can be found it may be extremely sensitive to noise. One has to use solution methods that utilize *a priori* information about the actual image, the blur, and the noise process in order to deal effectively with these undesirable features and obtain a satisfactory solution. Such methods that combat these features are called *regularization* methods. Therefore, restoration algorithms are in fact regularization methods. *A priori* information can be used in defining the models of the actual image, the blur, and the noise process, which are then utilized in the restoration process. The parameters of these models should be identified prior to restoration. The main contribution of this book is to develop novel methods, iterative in nature, for both identification and restoration.

The first four chapters of the book are introductory in nature and they provide a concise tutorial exposure of the fundamentals of image restoration. A novel iterative image restoration algorithm is presented in Chapter 5. A unifying overview of maximum likelihood (ML) methods for identification of image and blur point spread function (PSF) model parameters, as well as the statistics of the noise process, is presented in Chapter 6, where the stage is set for the next three chapters in which the authors introduce novel iterative ML-based methods for simultaneous identification and restoration.

In the first chapter, the authors define the image restoration problem and introduce its main aspects, namely (1) modeling, (2) identification, and (3) regularization. The emphasis in Chapter 2 is on modeling, where modeling of image/blur formation, the ideal image, and the blurring PSF are discussed. For image/blur formation, linear convolutional and superposition integral models are considered. Autoregressive (AR) models are discussed for modeling the ideal image. Discussion of PSF models is concentrated on specific, commonly occurring blur types, such as motion, out-of-focus, atmospheric turbulence, and scatter blurs. In the next chapter, Chapter 3, a general review of restoration algorithms is furnished. The authors classify various restoration algorithms into three distinct classes: (1) stochastic, (2) algebraic, and (3) multiple constraints methods. (Indeed, there is more than one way of classifying the restoration algorithms, and this particular classification is one of them.) The basic principles of methods such as Bayesian estimation, Wiener and Kalman filtering, Tikhonov-Miller regularization, and projections onto convex sets are reviewed in this chapter. Chapter 4 is closely related to one of the main areas of contribution of this thesis. It concentrates on iterative restoration methods, and reviews VanCittert's and Bialy iterations, as well as the iterative Tikhonov-Miller regularization.

The contribution of the thesis in the area of iterative image restoration is presented in Chapter 5, where an extension of Miller regularization is developed to perform restoration with reduced artifacts. In the first part of the chapter, an analysis of how the regularization process may introduce some undesirable artifacts in the restored image is given. (Artifacts can in fact be viewed as the price paid for combatting the undesirable features.) The origins and the characteristics of these artifacts suggest that the restoration algorithm should be adaptive in order to reduce these artifacts. To this end, the authors develop a spatially adaptive extension of the iterative Tikhonov-Miller regularization method in the second part of the chapter. Further, they incorporate additional convex-type constraints to this extension. Experimental results illustrate the effectiveness of the resulting method in producing restorations with reduced artifacts.

Chapter 6 provides a review of existing methods for identification of image and blur PSF models and the variance of the noise process under a unifying ML parameter estimation framework. Unification of seemingly different identification methods is a rather valuable contribution of this chapter. The ML-based approaches require the optimization of a nonlinear likelihood functional, which is usually performed via some gradient-based search procedure. A more elegant approach, which does not require gradient-based search, is the utilization of the expectation maximization (EM) algorithm and optimization of the likelihood functional in an iterative fashion. Application of the EM algorithm to the identification problem in image restoration is the second major contribution of this thesis and is discussed in the last two chapters of the book.

The EM algorithm is a general iterative method to compute the ML estimates, provided that the observed data can be viewed as "incomplete," which is indeed the case in image restoration. Unlike the conventional gradient-based methods, the EM algorithm avoids directly operating on nonlinear functionals. Instead, it requires the solution of linear equations. A general review of the EM algorithm and its application to the identification problem is discussed in the first two parts of Chapter 7. The EM algorithm iterates between an "expectation" (E) and a "maximization" (M) step. Parameter estimates are obtained in the M step. In the E step, a linear minimum mean square error (LMMSE) restoration of the image is obtained using the parameters estimated in the previous M step. Thus, the EM algorithm, upon convergence, yields the restoration of the image obtained by the estimated model parameters.

The last chapter explains several practical difficulties in implementing the EM algorithm and proposes methods to resolve these difficulties. These difficulties arise mainly due to the large number of unknown parameters, which may result in inaccurate estimates, and due to the requirement that the extent of the PSF should be known *a priori*. Models with few parameters are possible in certain cases, such as for the motion and out-of-focus motion blur PSFs, and can be used to remedy the first difficulty. A hierarchical approach is proposed to avoid the need for *a priori* knowledge of the extent of the PSF. In this approach, the algorithm is applied first to the image at a low-resolution hierarchical level where the extent of the PSF is assumed to be small (for example, 3×3 pixels). Then, the identification results are passed to the next higher resolution level where they are used as initial estimates for the EM procedures that try a predetermined set of larger sizes for the extent of the PSF. The size that results in the largest likelihood function value is chosen as the estimate for that resolution level.

Overall, this monograph is rather specialized due to the fact that it was written as a doctoral dissertation. On the other hand, it offers well-written and well-organized tutorial material in its area of specialization in addition to important recent research results. It is valuable as a reference book as well as a supplementary textbook for an advanced course in image restoration.

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