object components. In [2], a binary choice is made between the two components, and one of two filters is chosen accordingly.

In practice, it has been found that overlapping of the sections gives a more pleasing final image. The value $\sigma_{D_i}^2$ is computed over a larger section U_i containing the points to be changed for the new section N_i, i.e., $N_i \subset U_i$. This allows smoother transition between sections and helps eliminate section boundary effects in the new image N.

In the example, Fig. 1, the images are 128 × 128 pixels. Fig. 1(a) is a noisy image I. Fig. 1(b) is the same image blurred globally by a low-pass filter. Fig. 1(c) shows the new image N which was processed by the above algorithm using a large section of 8 × 8 pixels (U_i) to generate a new section of 4 × 4 pixels (N_i). The complete computation took less than 11 s on a CDC 7600.

References

[1] G. L. Anderson and A. N. Netravali, "Image restoration based on a subjective criterion," *IEEE Trans. Syst., Man, Cybern.*, vol. SMC-6, no. 12, pp. 845–853, Dec. 1976.
[2] N. E. Nahi and A. Habibi, "Decision-directed recursive image enhancement," *IEEE Trans. Circuits and Systems*, vol. CAS-22, no. 3, Mar. 1975.

Book Reviews

Nonlinear Control Engineering—Describing Function Analysis and Design—D. P. Atherton (New York and London: Van Nostrand Reingold, 1975, 627 pp.). *Reviewed by D. R. Towill, Department of Mechanical Engineering, University of Wales, Institute of Science and Technology, Cardiff CF1 3NU, Wales.*

It is a paradox of life that whilst a high-order, high-performance electrohydraulic servomechanism can be adequately described for the conditions under test by a linear transfer function [1], a simple instrument servomechanism, typically met by engineering students in an introductory control course, cannot be so described [2]. In fact, it is likely that even the simplest experimental results on the instrument servomechanism may need deadzone, saturation, and backlash to be considered present before the results can be properly explained, in which case the text under review is an ideal source to turn to. The author suggests that the contents may be rearranged into two separate first and second one-term courses in nonlinear control systems, which is a convenient breakdown for review purposes.

After a brief Chapter 1 on the fundamentals of nonlinear systems, Chapter 2 presents a detailed account of the phase-plane technique including the effect of coulomb friction, error limiting, torque saturation, and backlash on the step response of a second-order system, together with an introduction to relay and optimum systems. Single sinusoidal-input describing functions for various nonlinear elements are evaluated in depth in Chapter 3, using both Fourier analysis and polynomial expansion techniques. In Chapter 4, single sinusoidal-input describing functions are used to determine limit-cycle existence, system compensation, closed-loop frequency response, jump resonance existence, and describing-function accuracy. Chapter 7 is an introduction to the mathematics of random signal analysis, including the optimization of linear systems via the mean-square-error criterion. The part of Chapter 8 relevant to the first course is arguably the derivation and measurement of the random signal plus bias describing function, plus the analysis of closed-loop systems with random inputs.

The second course commences with Chapter 5, which evaluates sinusoid plus bias and two sinusoidal-input describing functions and introduces the incremental describing-function concept. Applications discussed include asymmetrical oscillations, limit-cycle stability, jump phenomenon, limit-cycle induction, limit-cycle quenching, dither signals, and subharmonic response. Chapter 6 then analyzes periodic modes in relay systems via time-domain and describing-function methods. Chapters 9–14 are devoted mainly to topics in which there have been significant developments since the preparation of Gelb and Van der Velde [3], the logical predecessor to the present text and which did not include as a matter of policy phase-plane material. Chapter 9 extends the describing function to the analysis of transient behavior, and covers the dynamic describing function, exponential describing function, and half-period describing function, with applications to the response of limit-cycling systems. Multivariable nonlinearities are studied via transform and orthogonal polynomial methods in Chapter 10, and Chapter 11 applies multiple-input describing functions to the removal of jump resonance and oscillations in a time-varying system. Chapter 12 describes recent work on nonlinear multivariable systems, including U.K. contributions of Rosenbrock, Macfarlane, and Mees. Quasi-linear modeling of double-valued nonlinearities to overcome earlier difficulties is outlined in Chapter 13, and Chapter 14 concludes the work by considering the behavior of nonlinear carrier systems.

Appendices list describing functions and harmonic coefficients for a wide range of nonlinearities. 187 student problems cover Chapters 2–12, and answers are given to 62 problems. As with [3], the references and bibliographies are most comprehensive. Some 15 percent of the references quoted are post 1968, which gives a very rough guide to the percentage of new work to be found in the text. Quite apart from the differences in coverage compared to [3], already noted, a major difference in treatment in the present text is the extensive use of polynomial expansion to determine describing functions.

The text is well written and illustrated. Topics not included which would have benefited the same audience are the use of the Fourier response analyzer [4] for rapid experimental measurement of describing functions, particularly a recent version which evaluates higher harmonics up to tenth order [5], and the response of nonlinear systems to pseudo-noise sequences. However, it might be felt that in view of the uncertainty and controversy surrounding the latter [6], [7], the author may have made a wise omission at this time.

References

[1] P. A. Payne, D. R. Towill, and K. J. Baker, "Predicting servomechanism dynamic performance variation from limited production test data," *Radio and Electronic Engineer*, vol. 40, no. 6, pp. 275–288, Dec. 1970.
[2] D. R. Towill and J. D. Lamb, "Pseudo-random signals test nonlinear controls," *Control Engineering*, vol. 17, pp. 59–63, 1970.
[3] A. Gelb and W. E. Van der Velde, *Multiple-Input Describing Functions and Nonlinear System Design*. New York: McGraw-Hill, 1968.
[4] C. S. Elsden, "A digital transfer function analyzer based on pulse rate techniques," *Automatica*, vol. 5, no. 1, pp. 51–60, 1969.
[5] S.E. Laboratories, *2001 Transfer Function Analyser Handbook*. Middlesex, U.K.: Feltham.
[6] H. Banasiewicz, S. E. Williamson, and W. F. Lovering, "Use of synchronized dither in pseudorandom-sequence testing," *Electron. Lett.*, vol. 9, no. 15, pp. 334–335, 1973.
[7] K. R. Godfrey and J. L. Douce, "Comment on use of synchronized dither in pseudorandom-sequence testing," *Electron. Lett.*, vol. 9, no. 19, pp. 450–451, 1973. (Reply by authors, 1973, no. 20, p. 480.)