

Additional References with Titles

Chapter 1

- T.S.HUANG: *Image Processing* (to be published by North-Holland, Amsterdam, 1976).
- T.S.HUANG, D.BARKER, S.BERGER: Iterative image restoration. *Appl. Opt.* **14**, No. 5, 1165–1168 (May, 1975).
- T.S.HUANG, J.BURNETT, A.DECZKY: The importance of phase in image processing filters (to appear in *IEEE Trans. on Acoustics, Speech, and Signal Processing*, December 1975).
- T.S.HUANG, P.NARENDRA: Image restoration by singular value decomposition (to appear in *Appl. Opt.*, September 1975).
IEEE Proc., Special issue on Digital Signal Processing (April, 1975).
IEEE Trans. on Circuits and Systems, Special issue on Digital Filtering and Image Processing (March, 1975).
- G.A.JULIEN, M.A.SID-AHMED: Stability constraints used in computeraided design of recursive digital filters. *IEEE Trans. Acoustics, Speech and Signal Processing ASSP-22*, No. 2, 153–158 (1974).
- A.V.OPPENHEIM, R.SCHAFFER: *Digital Signal Processing*. (Prentice-Hall, New York, 1975).
- L.RABINER, B.GOLD: *Theory and Applications of Digital Signal Processing*. (Prentice-Hall, New York, 1975).
- A.ROSENFELD, A.C.KAK: *Digital Picture Processing* (to be published by Academic Press, New York, 1976).

Chapter 2

- H.C.ANDREWS, C.L.PATTERSON: Outer products and their uses in digital image processing. *Am. Math. Monthly* **82**, No. 1, 1–15 (1975).

Chapter 3

- Y.KAMP, J.P.THIRAN: Maximally flat nonrecursive two-dimensional digital filters. *IEEE Trans. Circuits and Systems CAS-21*, No. 3, 437–449 (1974).
- Y.KAMP, J.P.THIRAN: Chebyshev approximation for two-dimensional nonrecursive digital filters. *IEEE Trans. Circuits and Systems CAS-22*, No. 3, 208–218 (1975).

Chapter 4

- N.K.BOSE, P.S.KAMAT: Algorithm for stability test of multi-dimensional filters. *IEEE Trans. Acoustics, Speech, Signal Proc. ASSP-22*, No. 5 (1974).
- N.K.BOSE, E.I.JURY: Positivity and stability test for multi-dimensional filters (discrete-continuous). *IEEE Trans. Acoustics, Speech, Signal Proc. ASSP-22*, No. 3 (1974).

- J. M. COSTA, A. N. VENETSANOPOULOS: Design of circularly symmetric two-dimensional recursive filters. *IEEE Trans. Acoustics, Speech, Signal Proc. ASSP-22*, No. 6 (1974).
- E. I. JURY: The theory and applications of the inners. *IEEE Proc.* **63**, No. 7, 1044–1068 (1975).
- G. A. MARIA, M. M. FAHMY: On the stability of two-dimensional digital filters. *IEEE Trans. Audio Electroacoustics AU-21*, 470–472 (1973).
- G. A. MARIA, M. M. FAHMY: An L_p design technique for two-dimensional digital recursive filters. *IEEE Trans. Acoustics, Speech, Signal Proc. ASSP-22*, No. 1 (1974).
- R. M. MERSEREAU, D. E. DUDGEON: The representation of two-dimensional sequences as one-dimensional sequences. *IEEE Trans. Acoustics, Speech, Signal Proc. ASSP-22*, No. 5 (1974).
- S. K. MITRA, A. D. SAGAR, N. A. PENDERGRAS: Realizations of two-dimensional recursive digital filters. *IEEE Trans. Circuits and Systems CAS-22*, No. 3 (1975).
- M.-D. NI, J. K. AGGARWAL: Two-dimensional digital filtering and its error analysis. *IEEE Trans. Computers C-23*, No. 9 (1974).
- D. D. SILJAK: Stability for two-variable polynomials. *IEEE Trans. Circuits and Systems CAS-22*, No. 3 (1975).

Chapter 5

- A. O. ABOUTALIB, L. M. SILVERMAN: Restoration of images degraded by curvi-linear motion; in *Second International Joint Conference on Pattern Recognition* (Copenhagen, 1974; IEEE Cat. No. 74CH0885-4C).
- J. J. BURKE: Estimating objects from their blurred and grainy images; in *Proceedings of the Technical Program. Electro-Optical Systems Design Conference* (West International Laser Exposition, San Francisco, 1974).
- B. R. FRIEDEN: Restoration of Pictures by Monte Carlo allocation of pseudograins; in *Second International Joint Conference on Pattern Recognition* (Copenhagen, 1974; IEEE Catalog No. 74CH0885-4C), p. 141.

Chapter 6

- R. T. CHIEN, W. E. SNYDER: Hardware for visual image processing. *IEEE Trans. Circuits and Systems CAS-22*, No. 6, 541–551 (1975).
- J. L. MANNOS, D. J. SAKRISON: The effect of visual criterion on the encoding of images. *IEEE Trans. Information Theory IT-20*, No. 4, 525–536 (1974).
- W. F. SCHREIBER: The effect of scanning speed on the S/N ratio of camera tubes. *Proc. IEEE* **52**, No. 2, 217 (1964).

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