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Image Wavelet Coding Systems: Part II of Set Partition Coding and Image Wavelet Coding Systems

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Abstract

This monograph describes current-day wavelet transform image coding systems. As in the first part, steps of the algorithms are explained thoroughly and set apart. An image coding system consists of several stages: transformation, quantization, set partition or adaptive entropy coding or both, decoding including rate control, inverse transformation, de-quantization, and optional processing (see Figure 1.6). Wavelet transform systems can provide many desirable properties besides high efficiency, such as scalability in quality, scalability in resolution, and region-of-interest access to the coded bitstream. These properties are

built into the JPEG2000 standard, so its coding will be fully described. Since JPEG2000 codes subblocks of subbands, other methods, such as SBHP (Subband Block Hierarchical Partitioning) [3] and EZBC (Embedded Zero Block Coder) [8], that code subbands or its subblocks independently are also described. The emphasis in this part is the use of the basic algorithms presented in the previous part in ways that achieve these desirable bitstream properties. In this vein, we describe a modification of the tree-based coding in SPIHT (Set Partitioning In Hierarchical Trees) [15], whose output bitstream can be decoded partially corresponding to a designated region of interest and is simultaneously quality and resolution scalable.

This monograph is extracted and adapted from the forthcoming textbook entitled *Digital Signal Compression: Principles and Practice* by William A. Pearlman and Amir Said, Cambridge University Press, 2009.

Contents

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Subband/Wavelet Coding Systems

1.1 Introduction

This monograph describes coding systems, primarily for images, that use the principles and algorithms explained in the first part. A complete coding system uses a conjunction of compression algorithms, entropy coding methods, source transformations, statistical estimation, and ingenuity to achieve the best result for the stated objective. The obvious objective is compression efficiency, stated as the smallest rate, in bits per sample, for a given distortion in lossy coding or smallest rate or compressed file size in lossless coding. However, other attributes may be even more important for a particular scenario. For example, in medical diagnosis, decoding time may be the primary concern. For mobile devices, small memory and low power consumption are essential. For broadcasting over packet networks, scalabilty in bit rate and/or resolution may take precedence. Usually to obtain other attributes, some compression efficiency may need to be sacrificed. Of course, one tries to obtain as much efficiency as possible for the given set of attributes wanted for the system. Therefore, in our description of systems, we shall also explain how to achieve other attributes besides compression efficiency.

References

[1] T. Acharya and P.-S. Tsai, *JPEG2000 Standard for Image Compression: Concepts, Algorithms and VLSI Architectures.* Hoboken, NJ: Wiley-Interscience, John Wiley & Sons, Inc., 2005.

[2] E. Christophe and W. A. Pearlman, "Three-dimensional SPIHT coding of volume images with random access and resolution scalability," *EURASIP Journal on Image and Video Processing*, vol. 2008, p. 13, doi:10.1155/2008/248905, 2008.

[3] C. Chrysafis, A. Said, A. Drukarev, A. Islam, and W. A. Pearlman, "SBHP — a low complexity wavelet coder," *IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP2000)*, vol. 4, pp. 2035–2038, 2000.

[4] P. C. Cosman, S. M. Perlmutter, and K. O. Perlmutter, "Tree-structured vector quantization with significance map for wavelet image coding," *Proceedings of 1995 Data Compression Conference (DCC '95)*, pp. 33–41, 28–30 March 1995.

[5] P. C. Cosman, S. M. Perlmutter, and K. O. Perlmutter, "Vector quantization with zerotree significance map for wavelet image coding," *Conference Record of the Twenty-Ninth Asilomar Conference on Signals, Systems and Computers*, vol. 2, pp. 1419–1423, 30 October–2 November 1995.

[6] E. A. B. da Silva, D. G. Sampson, and M. Ghanbari, "A successive approximation vector quantizer for wavelet transform image coding," *IEEE Transactions on Image Processing*, vol. 5, no. 2, pp. 299–310, 1996.

[7] S.-T. Hsiang, "Highly scalable subband/wavelet image and video coding," PhD Thesis, Electrical, Computer and Systems Engineering Dept., Rensselaer Polytechnic Instute, Troy, NY 12180, USA, http://www.cipr.rpi.edu/ hsiang/thesis_dl.htm+, 2002.

[8] S.-T. Hsiang and J. W. Woods, "Embedded image coding using zeroblocks of subband/wavelet coefficients and context modeling," *IEEE International Conference on Circuits and Systems (ISCAS2000)*, vol. 3, pp. 662–665, 2000.

[9] A. Islam and W. A. Pearlman, "An embedded and efficient low-complexity hierarchical image coder," in *Proceedings SPIE, Visual Communications and Image Processing '99*, pp. 294–305, 1999.

[10] ISO/IEC 15444-1, *Information Technology-JPEG2000 Image Coding System, Part 1: Core Coding System*, 2000.

[11] ISO/IEC 15444-2, *Information Technology-JPEG2000 Extensions, Part 2: Core Coding System*, 2001.

[12] E. Khan and M. Ghanbari, "Very low bit rate video coding using virtual SPIHT," *Electronics Letters*, vol. 37, no. 1, pp. 40–42.

[13] A. A. Moinuddin and E. Khan, "Wavelet based embedded image coding using unified zero-block-zero-tree approach," *Proceedings on IEEE International Conference on Acoustics, Speeech and Signal Processing (ICASSP 2006)*, vol. 2, pp. 453–456, 2006.

[14] D. Mukherjee and S. K. Mitra, "Successive refinement lattice vector quantization," *IEEE Transactions on Image Processing*, vol. 11, no. 12, pp. 1337–1348, December 2002.

[15] A. Said and W. A. Pearlman, "A new, fast and efficient umage codec based on set partitioning in hierarchical trees," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 6, no. 3, pp. 243–250, June 1996.

[16] J. M. Shapiro, "Embedded image coding using zerotress of wavelet coefficients," *IEEE Transactions on Signal Processing*, vol. 41, no. 12, pp. 3445–3462, 1993.

[17] R. R. Shively, E. Ammicht, and P. D. Davis, "Generalizing SPIHT: A family of efficient image compression algorithms," *Proceedings on Acoustics, Speech, and Signal Processing 2000 (ICASSP 2000)*, vol. 4, pp. 2059–2062, 2000.

[18] D. S. Taubman, "High performance scalable image compression with EBCOT," *IEEE Transactions on Image Processing*, vol. 9, no. 7, pp. 1158–1170, 2000.

[19] D. S. Taubman and M. W. Marcellin, *JPEG2000: Image Compression Fundamentals, Standards, and Practice.* Boston/Dordrecht/London: Kluwer Academic Publishers, 2002.

[20] F. W. Wheeler and W. A. Pearlman, "SPIHT image compression without lists," *Proceedings of IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP 2000)*, vol. 4, pp. 2047–2050, 2000.