A Robust Image Compression Algorithm using JPEG 2000 Standard with Golomb Rice Coding

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Summary
Today's communication is mostly in the form of voice and data. The amount of data and voice that are transferred from one part of the world to another is enormous. To refute the issue of bandwidth from the systems in vogue today, and to help provide acceptable quality of services for voice communications, the problem of image compression and decompression has been dealt in this paper. This paper analyzes JPEG 2000 standard with Golomb Rice Technique for various wavelet transforms like D2, D4, D8, D10, D12, Haar and DMEY for compression and decompression of image signals. Further the various wavelet transforms with Golomb Rice technique were tested on 25 image samples for compression and it was found that the DMEY wavelet based Golomb Rice technique achieves a RMSE of nearly zero and number of samples saved around 49.965 % on an average compared to other wavelet, which shows that DMEY is best suited for image compression.

Key words:
Wavelet, JPEG 2000, Golomb Rice, Image compression.

1. Introduction

The communication in today's world is mostly in form of voice, data or image transmission. In particular the voice and image occupies an enormous amount of bandwidth. So in order to reduce the bandwidth and increase the throughput of transmission various compression techniques [1-4] have evolved. This paper discusses about the image compression technique.

Image is a very basic way for humans to convey information to one another. With a bandwidth of only 4 kHz, image can convey information with the emotion of a human voice. As a result a greater emphasis is being placed on the design of new and efficient image coders for voice communication and transmission. Today applications of image coding and compression have become very numerous. Many applications involve the real time coding of image signals, for use in mobile satellite communications, cellular telephony, and audio for videophones or video teleconferencing systems. Other applications include the storage of image for image synthesis and playback, or for the transmission of voice at a later time. Some examples include voice mail systems, voice memo wristwatches, voice logging recorders and interactive PC software. Traditionally image coders can be classified into two categories: waveform coders and analysis/synthesis vocoders [5-7, 9] (from "voice coders"). Waveform coders attempt to copy the actual shape of the signal produced by the microphone and its associated analogue circuits [8, 10-11].

A popular waveform coding technique is pulse code modulation (PCM), which is used in telephony today. Vocoders use an entirely different approach to image coding, known as parameter-coding, or analysis/synthesis coding where no attempt is made at reproducing the exact image waveform at the receiver, only a signal perceptually equivalent to it. These systems provide [12-15] much lower data rates by using a functional model of the human speaking mechanism at the receiver. One of the most popular techniques for analysis-synthesis coding of image is called Linear Predictive Coding (LPC).

This paper looks at a new technique for analyzing and compressing image signals using various wavelets. Very simply wavelets are mathematical functions of finite duration with an average value of zero that are useful in representing data or other functions. Any signal can be represented by a set of scaled and translated versions of a basic function called the "mother wavelet". This set of wavelet functions forms the wavelet coefficients at different scales and positions and results from taking the wavelet transform of the original signal. The coefficients represent the signal in the wavelet domain and all data operations can be performed using just the corresponding wavelet coefficients [16-20].

Image is a non-stationary random process due to the time varying nature of the human image production system. Non-stationary signals are characterized by numerous transitory drifts, trends and abrupt changes. The localization feature of wavelets, along with its time-frequency resolution properties makes them well suited for coding image signals [1].

The paper is organized as follows: Section 2 discusses about the wavelet transform. Section 3 gives introduction

Manuscript received December 5, 2010
Manuscript revised December 20, 2010

to JPEG standard while section 4 explains Golomb Rice technique. Section 5 focuses on the design of image codec. Section 6 shows the simulation results featuring the percentage number of samples saved and the root mean square error for Haar, D2, D4, D8, D10, D12 and DMEY wavelets.

2. Wavelet Transforms

The fundamental idea behind wavelets is to analyze according to scale. The wavelet analysis procedure is to adopt a wavelet prototype function called an analyzing wavelet or *mother* wavelet [12, 21-25]. Any signal can then be represented by translated and scaled versions of the mother wavelet.

Wavelet analysis is capable of revealing aspects of data that other signal analysis techniques such as Fourier analysis miss aspects like trends, breakdown points, discontinuities in higher derivatives, and self-similarity. Furthermore, because it affords a different view of data than those presented by traditional techniques, it can compressor de-noise a signal without appreciable degradation [7].

Taking the Fourier transform of a signal can be viewed as a rotation in the function space of the signal from the time domain to the frequency domain. Similarly, the wavelet transform can be viewed as transforming the signal from the time domain to the wavelet domain. A wavelet prototype [26]function at a scale s and a spatial displacement u is defined as:

$$\psi_{s,u}(x) = \sqrt{s}\psi\left[\frac{(x-u)}{s}\right] \quad (1)$$

An advantage of wavelet transforms is that the windows vary. Wavelet analysis allows the use of long time intervals where we want more precise low-frequency information, and shorter regions where we want high-frequency information. This is achieved by the varying nature of the basis function [8]

3. JPEG Standard

In this section, the JPEG compression scheme, this was created about 2 decades back to create an international standard for image compression in the Consultative Committee on International Telephone and Telegraph (CCITT) and the International Standards Organization (ISO), is introduced. It is a lossy compression [14-15, 17, 19, 21] scheme based on DCT algorithm. Also, there is a JPEG lossless compression scheme proposed for some applications with the requirement for lossless ness in the quality of the decompressed image which is normally used for medical images. The JPEG lossless scheme is based on a completely different approach to the lossy scheme. In this paper, lossless JPEG is not discussed.

JPEG is an acronym of Joint Photographic Experts Group [22]. It is a branch of a committee in the International Standard Organization (ISO) for still image compression standards. A general flow chart of JPEG compression is shown in Figure 1.

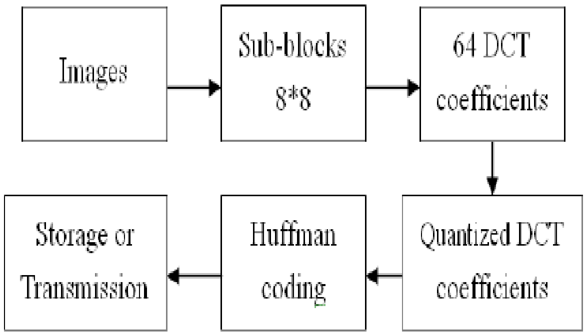

Figure 1: A General JPEG Standard Block Diagram

The quantization procedure quantizes the DCT coefficients to the quantization steps at corresponding positions in the quantization table. For different block sizes, the quantization tables are different. For example, Table 1presents the quantization tables for block sizes of 8*8 pixels. These quantization steps in the quantization tables are determined according to the importance of the coefficients in the frequency domain. There exist many evaluation methods for determining the importance of the coefficients. Different evaluation methods will produce a different quantization table that affects the image quality.

However, all of these quantization procedures are for quantizing the coefficients to become integers, so that the encoding procedure performs easily with Huffman coding or other coding methods.

The compression method is usually lossy, meaning that some original image information is lost and cannot be restored, possibly affecting image quality. There is an optional lossless mode defined in the JPEG standard; however, that mode is not widely supported in products. There is also an interlaced "Progressive JPEG" format, in which data is compressed in multiple passes of progressively higher detail. [23-27]. This is ideal for large images that will be displayed while downloading over a slow connection, allowing a reasonable preview after receiving only a portion of the data. However, progressive JPEGs are not as widely supported, and even some software which does support them (such as some versions of Internet Explorer) only displays the image once it has been completely downloaded. There are also many medical imaging and traffic systems that create and process 12-bit JPEG images, normally grayscale images.

The 12-bit JPEG format has been part of the JPEG specification for some time, but again, this format is not as widely supported.

4. Golomb Rice Technique

Golomb–Rice coding is a simple, yet efficient way to compress data. The complexity advantages of the Golomb–Rice codes have led the JPEG committee to adopt them as part of the JPEG-LS standard [7]. The Consultative Committee for Space Data Systems (CCSDS) recommends the use of Golomb–Rice codes to compress the data of on board scientific instruments that require a minimum expenditure of power and computational resources [8]. Recently the MPEG committee has proposed the use of Golomb–Rice codes for lossless compression of audio [9].

4.1 Introduction

The Golomb codes were initially proposed in [10] as a means to encode the run lengths of favorable events of a binary source. Golomb's results are most applicable when p_m^o , where is the p_0 probability of the favorable events and an integer. Golomb also noticed that the special case when the parameter is a power of two accepts simple encoding and decoding algorithms. Later, Gallager [11] showed that Golomb's codes are Huffman codes for a source of nonnegative integers, with geometric distribution.
It follows that Golomb codes are optimal for encoding geometric sources. The Golomb code for the special case, $m = 2^k$ with k being a positive integer *n,* is easily obtained by the following procedure. To encode a nonnegative integer simply concatenate the unary code for $\lfloor n / m \rfloor$ with a 0 and with the natural binary code for, where is the largest integer not exceeding. In practice, most sources of interest do not follow a geometric distribution. However, it has been shown in [13] that the adaptive Golomb–Rice codes are optimal for *digital* sources with a Laplacian distribution. As the Golomb–Rice encoding accepts only nonnegative integers, a suitable mapping is required to encode signed numbers. We define such a mapping for signed analog values below. Most sources of interest have a high degree of correlation between their samples. Therefore, a de-correlation step is usually placed before the encoding. The - aims to remove redundancies, allowing greater compression rates. Fortunately, the de-correlated output of most sources of interest closely follows a Laplacian distribution, making the proposed techniques applicable. Typically, differencing between consecutive sample values results in de-correlation as shown in Figure 2.

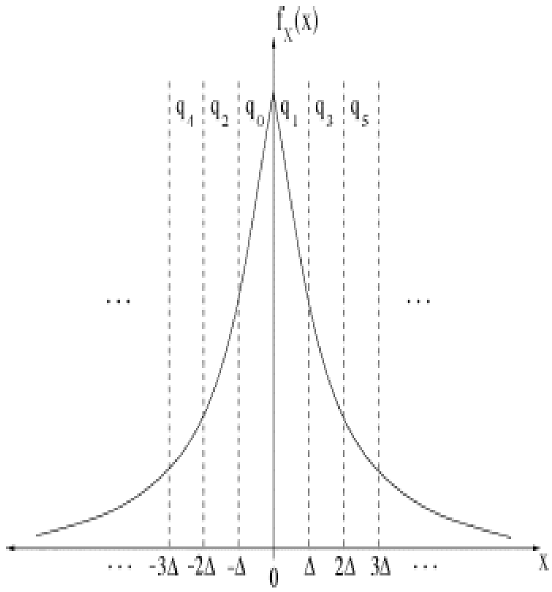

Figure 2: Uniform distribution of Golomb- Rice technique

4.2 Proposed Coding Scheme

Initially the image is converted into samples or binary data. Let 'n' be the number of bits in the binary data. CT is called coupling transitions [4,9] of the data.
Algorithm:

1. Calculate the number of CT of the given data. $A = \{a_1, a_2, a_3, ... a_n\}$
2. ***If*** CT $\geq (\frac{n}{2} - 1)$ ***then***
   begin
   Consider the bit reversal order of the data which is currently on the bus $A = \{a_1, a_2, a_3, ... a_n\}$.
   Let the new data be Z . Now rearrange the new data as First Group (FG) and Second Group (SG) and let the code data is P .
   end
3. Calculate both coupling and self transitions of FG and SG. Let these transitions be FGT and SGT
   if (FGT>SGT) ***then***
   begin
   DO: Flip all the FG bits and convert to gray code and append with 2 extra bits 11, and transmit.
   end

else
begin
DO: Flip all the SG bits convert to gray code and append with 2 extra bits 10, and transmit.
end

else
begin
DO: Send the data as is with extra bits 00 and transmit.
end

4.3 Descriptive Example

To illustrate the proposed coding scheme consider an 8 bit data *A*= {1, 0, 1, 0, 1, 0, 1, 1} which is presently on the bus. The Coupling transitions (CT) of this data is 6 so the new proposed technique is used. Now consider bit reversal order for this data so the new data would be *Z*= {1,1,0,0,1,1,0,1}. The Coupling transitions of the FG are 1 and that of SG is 2. So invert the SG bits then data to be transmitted would be *P*= {1,1,0,0,0,0,1,0}. Now convert the data *P* to gray code so the new data is *Q* = {1,0,0,0,0,0,1,0}. So CT of data *Q* which is to be transmitted is 2. So the CT have come down 6 to 2 which shows that reduction in power. So the novel technique can be used for low power applications.

5. Design of Image Codec

The generalized block diagram of a codec is shown in Figure 3.The block diagram consists of the wavelet transformation block, thresholding and encoding at the transmitter side and decoder and inverse transformation block at the receiver side. The image signal given as the drive to the wavelet transformation block.

5.1 Wavelet Transformation

The wavelet transform applies the smoothing and the wavelet function to the input image samples. If the original data set has N values, the smoothing and wavelet function will be applied to calculate N/2 smooth values and differences (reflecting change in the data) values. There by the high frequency and the low frequency components are resolved or decompose [7]. In this paper we applied Haar, D2, D4, D8, D10, D12, DMEY wavelet and found out which gives better compression ratio as well as less RMSE.

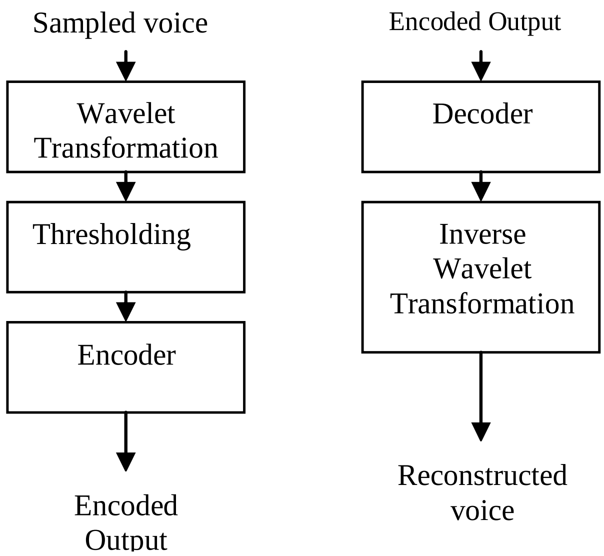

Figure 3: Image Coder/Decoder for compression and decompression

5.2 Thresholding

It is known that the high frequency components always carry less information as compared to the low frequency components. Based on this proven fact, the high frequency components are taken the process of amplitude thresholding is done. This is done by selection of a suitable threshold value from the high frequency components, and then setting to zero, the components below the modulus of the threshold value.

5.3 Encoding

The run length encoding procedure was adopted to encode the sample values. The values which are non-zero are kept as such, and the zeroes are represented by counting the number of zeroes and then putting a zero followed by the value of the number of zeroes counted. The number of zeroes depends upon the threshold value that was set. The higher the threshold, the higher the number of zeroes and the compression ratio will be increased.

5.4 Inverse Wavelet Transform

The inverse transform works on N data elements, where the first N/2 elements are smoothed values and the second N/2 elements are wavelet function values. The inner product that is calculated to reconstruct a signal value is calculated from two smoothed values and two wavelet values. Logically, the data from the end is wrapped around from the end to the start.

6. Simulation Results

This section presents experimental results of the proposed method. The evaluation procedure is described in Subsection 6.1. Subsection 6.2 then shows these processed images and these tabulated data for comparison between the proposed method and the standard JPEG method.

As, JPEG is a fixed block-size DCT based compression technique but involves wavelet based compression technique. Thus, it is enough to compare the experimental results of the modified proposed method based on DCT techniques with results of standard JPEG compression for showing the enhancement in terms of Golomb Rice Technique. The Golomb Rise module can be inserted into the traditional JPEG compression scheme where it can replace the standard DCT block.

The experimental inputs for the proposed methods are the images, Lena, Rine, Girl, House, River, Animal as shown in Figure 4.

Figure 4. USID Benchmarks

Thus, the quantized DCT coefficients in the JPEG compression scheme can be "compressed" further and new compressed coefficient can be obtained. Each of these compressed coefficients is only represented by two values; the threshold and quantized value which can be also called intercept values.

In other words, if a regression line presents more than 3 quantized DCT coefficients, the storage of the quantized DCT coefficients can be further compressed. That "compression" process also affects some errors. These errors can be also controlled within the new threshold value.

The images have a size of 128*128. The comparison between the proposed method and the JPEG compression method is focused on the compressed image size and the decompressed image quality, which is displayed in Table 1. With these six images, the proposed method behaves better at a high compression rate. For comparisons, JPEG Compression scheme is implemented with MATLAB that performs on a personal computer with an Intel CPU of 2.3GHz and a memory of 2GB. The operation system used was Windows 7 64 bit.

The quality factor, which has a value from 4 to 34 which controls the compression ratio. A Q value of 4 is for the highest compression rate but results in poor image quality. If Q is 12, the compressed loss in image quality will be very small after decompression. In other words, the file size used to store the compressed image might be larger. The proposed method is unfortunately good for the high compression rate only, so that the comparison is set especially for a higher compression rate in which the image quality is medium or low which are given in the Tables 1-6. All the values are compared with t-value technique which is claimed to be best in the literature.

Table1: Comparison with JPEG—Lena (Observe the PSNR values of proposed method and JPEG)

Lena					
t-value	**Proposed**		**Q-Value**	**JPEG**	
	Size	PSNR		Size	PSNR
1	12.768	34.09	34	12.686	38.14
2	19.892	33.12	24	19.923	37.98
3	13.879	36.98	25	13.796	37.09
4	9.786	37.98	12	9.768	49.01
5	9.872	31.81	21	9.823	35.98
6	12.164	32.98	17	12.648	45.98
7	6.876	21.98	8	6.763	31.09
8	8.654	12.89	4	8.541	18.98

Table 2: Comparison with JPEG—Rine (Observe the PSNR proposed values of method and JPEG)

Rine					
t-value	**Proposed**		**Q-Value**	**JPEG**	
	Size	PSNR		Size	PSNR
1	14.253	31.92	34	12.486	43.14
2	11.482	29.47	24	18.923	34.98
3	6.683	43.18	25	11.775	36.87
4	12.351	33.80	12	10.765	45.87

5	11.928	33.96	21	19.098	54.09
6	9.694	7.317	17	13.648	43.98
7	12.351	15.31	8	7.657	28.09
8	12.351	11.47	4	4.768	8.98

Table 3: Comparison with JPEG—Girl (Observe the PSNR values of proposed method and JPEG)

Girl					
t-value	Proposed		Q-Value	JPEG	
	Size	PSNR		Size	PSNR
1	12.763	27.66	34	17.093	27.61
2	10.482	25.54	24	16.551	24.62
3	16.683	37.43	25	19.597	25.24
4	15.983	29.29	12	17.512	16.09
5	18.961	29.43	21	17.546	29.73
6	10.981	6.34	17	15.626	7.98
7	12.017	13.27	8	8.403	7.54
8	11.912	9.94	4	6.551	7.78

Table 4: Comparison with JPEG—House (Observe the PSNR proposed values of method and JPEG)

House					
t-value	Proposed		Q-Value	JPEG	
	Size	PSNR		Size	PSNR
1	17.447	22.24	34	15.802	43.10
2	19.614	28.77	24	20.444	34.94
3	16.362	21.88	25	22.048	39.04
4	12.290	35.49	12	25.218	26.68
5	15.901	20.88	21	14.842	36.62

6	6.002	28.64	17	20.350	27.50
7	11.924	12.05	8	21.456	35.58
8	1.592	6.93	4	23.507	43.89

Table 5: Comparison with JPEG—River (Observe the PSNR values of proposed method and JPEG)

River					
t-value	Proposed		Q-Value	JPEG	
	Size	PSNR		Size	PSNR
1	12.976	24.66	34	20.09	40.18
2	16.998	26.89	24	21.91	43.82
3	11.386	25.97	25	21.16	42.32
4	10.624	23.45	12	19.11	38.22
5	11.873	22.29	21	18.16	36.33
6	12.949	11.95	17	19.73	29.47
7	12.504	20.92	8	17.04	34.09
8	11.293	10.79	4	18.79	27.59

Table 6: Comparison with JPEG—Animal (Observe the PSNR values of proposed method and JPEG)

Animal					
t-value	Proposed		Q-Value	JPEG	
	Size	PSNR		Size	PSNR
1	17.200	13.60	34	24.80	52.00
2	12.374	14.48	24	18.17	37.14
3	15.217	9.85	25	17.97	37.68
4	15.598	10.57	12	19.28	40.43
5	18.195	15.48	21	28.23	28.04

6	11.224	12.31	17	24.21	29.46
7	11.304	12.46	8	14.49	35.74
8	14.619	8.72	4	15.91	22.81

7. Conclusion

The results show that the coding efficiencies of JPEG 2000 standard and GR codes are sensitive to variable source parameters, and GR based codes outperform the standard JPEG 2000 compression in the environment where Q values changes frequently , and the situation is reversed in the context of changing pdf shape parameter. We proposed modified JPEG 2000 compression technique and the performance of hybrid Golomb codes is 10% higher than original JPEG compression.

Acknowledgments

The first author would like to thank Dr.I.Gopal Reddy-Director, Dr. O. Mahesh-Principal and Management of Priyadarshini College of Engineering & Technology, Nellore for their encouragement in doing this work. He is very grateful to Dr.G.Harinatha Reddy-Head of the Department of E.C.E and for his valuable suggestions during this work.

References

[1] T Pevný and J. Fridrich, “Detection of double-compression in JPEG images for applications in steganography,” IEEE Trans. Inf. Forensics Security, vol. 3, no. 2, pp. 247–258.
[2] H. Farid, “Exposing digital forgeries from JPEG ghosts,” IEEE Trans. Inf. Forensics Security, vol. 4, no. 1, pp. 154–160, Mar. 2009.
[3] Z Lin, J. He, X. Tang, and C. -K. Tang, “Fast, automatic and finegrained tampered JPEG image detection via DCT coefficient analysis,” Pattern Recognit., vol. 42, pp. 2492–2501, 2009.
[4] A.Westfeld, “High capacity despite better steganalysis (F5-A steganographic algorithm),” in Proc. 4th Int. Workshop Information Hiding, 2001, vol. 2137, pp. 289–302, Lecture Notes in Computer Science.
[5] N Provos, “Defending against statistical steganalysis,” in Proc. 10th USENIX Security Symp., Washington, DC, 2001.
[6] R. Yang, Y. Q. Shi, and J. Huang, “Defeating fake-quality MP3,” in Porc. ACMMultimedia and Security’09, Princeton, NJ, Sep. 7–8, 2009.
[7] W Wang and H. Farid, “Exposing digital forgeris in video by detecting double MPEG compression,” in Porc. ACM Multimedia and Security’06, Geneva, Switzerland, Sep. 26–27, 2006.
[8] J Lukáˇs and J. Fridrich, “Estimation of primary quantization matrix in double compressed JPEG images,” in Proc. Digital Forensic Research Workshop, Cleveland, OH, Aug. 2003
[9] T Pevný, J. Fridrich, Detection of Double-Compression in JPEG Images for Applications in Steganography [J], 2008,3(2):247~258
[10] H. Farid, Exposing Digital Forgeries From JPEG Ghosts [J], IEEE Transactions on Information Forensics and Security archive, 2009,4(1):154-160
[11] D.- Galleger, Y.-Q. Shi, and W. Su, A generalized benford’s law for jpeg coefficients and its applications in image forensics [J], in Proc. SPIE Security, Steganography, and Watermarking of Multimedia Contents, 2007, vol. 6505, p. 58.
[12] J He, Z. Lin, L.Wang, and X. Tang, Detecting doctored jpeg images via dct coefficient analysis [J], in ECCV’06, 2006, vol. III: 423-435.
[13] J Kovacevic and W. Sweldens, “Wavelet families of increasing order in arbitrary dimensions,” IEEE Trans. Image Process., vol. 9, no. 3, pp. 480–496, Mar. 2000.
[14] H. A. M. Heijmans and J. Goutsias, “Nonlinear multiresolution signal decomposition schemes-part II: Morphological wavelets,” IEEE Trans. Image Process., vol. 9, no. 11, pp. 1897–1913, Nov. 2000.
[15] E J. Candès and D. L. Donoho, “Curvelets – A surprisingly effective nonadaptive representation for objects with edges,” in Curve and Surface fitting,A. Cohen, C. Rabut, and L. L. Schumaker, Eds. Nashville, TN: Vanderbilt Univ. Press, 2000, pp. 105–120.
[16] E Pennec and S. Mallat, “Image compression with geometrical wavelets,” in Proc. IEEE Int. Conf. Image Processing, Vancouver, BC, Canada, Sep. 2000, vol. 1, pp. 661–664.
[17] M N. Do and M. Vetterli, “Contourlets: a directional multiresolution image representation,” in Proc. IEEE Int. Conf. Image Processing, Rochester, NY, Sep. 2002, vol. 1, pp. I–357–I–360.
[18] R Claypoole, R. Baraniuk, and R. Nowak, “Adaptive wavelet transforms via lifting,” in Proc. IEEE Int. Conf. Acoustics, Speech, and Signal Processing, May 1998, vol. 3, pp. 1513–1516.
[19] J Kliewer, A. Huebner, and D. J. Costello, Jr., “On the achievable extrinsic information of inner decoders in serial concatenation," in Proc. IEEE International Symp. Inform. Theory, Seattle, WA, July 2006.
[20] S. ten Brink, “Code characteristic matching for iterative decoding of serially concatenated codes," Annals Telecommun., vol. 56, no. 7-8, pp. 394-408, July-Aug. 2001.
[21] F Brännstrom, L. Rasmussen, and A. Grant, “Optimal puncturing ratios and energy distribution for multiple parallel concatenated codes," IEEE Trans. Inform. Theory, vol. 55, no. 5, pp. 2062-2077, May 2009.
[22] R R. Thobaben, “EXIT functions for randomly punctured systematic codes," in Proc. IEEE Inform. Theory Workshop (ITW), Lake Tahoe, CA, USA, Sept. 2007.
[23] V Mannoni, P. Siohan, and M. Jeanne, “A simple on-line turbo estimation of souurce statistics for joint-source channel LC decoders: application to MPEG-4 video," in

Proc. 2006 International Symp. Turbo Codes, Munich, Germany, Apr. 2006.
[24] C. Guillemot and P. Siohan, “Joint source-channel decoding of variable length codes with soft information: a survey," EURASIP J. Applied Signal Processing, no. 6, pp. 906-927, June 2005.
[25] J Hagenauer, E. Offer, and L. Papke, “Iterative decoding of binary block and convolutional codes," IEEE Trans. Inform. Theory, vol. 42, no. 2, pp. 429-445, Mar. 1996.
[26] A Ashikhmin, G. Kramer, and S. t. Brink, “Extrinsic information transfer functions: model and erasure channel properties," IEEE Trans. Inform. Theory, vol. 50, no. 11, pp. 2657-2673, Nov. 2004.
[27] J Hagenauer and N. Goertz, “The turbo principle in joint source-channel coding," in Proc. IEEE Inform. Theory Workshop (ITW), Paris, France, Apr. 2003, pp. 275-278.

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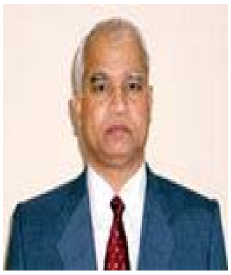

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