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Unequal Error Protection for Region of Interest with Embedded Zerotree Wavelet

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***Abstract*—**This paper describes a new method of unequal error protection (UEP) for region of interest (ROI) with embedded zerotree wavelet algorithm (EZW). ROI technique is important in applications with different parts of importance. In ROI coding, a chosen ROI is encoded with higher quality than the background (BG). Unequal error protection of image is provided by different coding techniques. In our proposed method, image is divided into two parts (ROI, BG) that consist of more important bytes (MIB) and less important bytes (LIB). The experimental results verify effectiveness of the design. The results of our method demonstrate the comparison of the unequal error protection (UEP) of image transmission with defined ROI and the equal error protection (EEP) over multiple noisy channels.

***Keywords*—**embedded zerotree wavelet (EZW), equal error protection (EEP), region of interest (ROI), RS code, unequal error protection (UEP)

I. Introduction

WITH the growing popularity of multimedia application and the spread of the Internet, the access of digital image becomes effortless. Hence, the image of content-based retrieval is essential for digital image libraries and databases. Image compression has become necessary in storage and transmission application. The objective of image compression is to decrease the bit rate for transmission or storage while maintaining an acceptable fidelity or image quality.

The early wavelet-based image coders [14], [15] were designed in order to exploit the ability of compacting energy on the typical wavelet decomposition by the entropy coding of its coefficients. However, the properties of wavelet coefficients can be exploited more efficiently. In that sense, Shapiro developed a wavelet-based coder [1] that considerably improves the previous wavelet proposals. The coder, called embedded zerotree wavelet coder (EZW), is mainly based on two observations:

- the similarity between the same kind of sub-bands in a wavelet decomposition, and
- a quantization based on a special kind of successive-approximations scheme that can be adjusted in order to get a specific bit rate.

Methods based on discrete wavelet transform (DWT) and EZW have been widely used for progressive transmission of large images [1], [16]-[18].

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Recently, much attention has been paid to the region of interest (ROI) coding since the functionality of ROI is suitable for many applications in which certain parts of an image are more meaningful than the other parts of the image [11]-[13].

The areas of ROI and EZW have already been described in a number of sources. With regard to medical images, ROI with EZW are frequently used tools, but it is used without error protection. If some error protection technique is used, it is mostly the Hamming code which corrects only the bit error and not the symbol error. Some of new ROI coding methods were described by Liu and Fan in [11] and by Wang and Bovik in [12]. Description of unequal error protection codes for image transmission was presented by Le and Liyana-Pathirana [7]. Idea of unequal error protection of images was described by Lo, Sanei and Nazarpour [10].The concept of image coding utilizing discrete wavelet transform and EZW has been initially proposed in [1] and various methods have been developed based on this idea [9], [15]. In [9], the concepts of DWT, EZW, progressive image transmission, and ROI have been utilized. In [15], an effective scheme for image compression has been proposed where the spatial-spectral features of the image have been taken into account in order to show that wavelet transform is particularly well suited for progressive transmission. Still image compression using embedded zerotree wavelet encoding was presented by Shingate, Sontakke and Talbar [2]. Wavelet based medical image compression using ROI EZW was presented in [3]. New view of the ROI based encoding of medical image which describes an effective scheme using lifting wavelets and SPIHT for telemedicine was presented in [4]. Fuzzy based image compression on ROI using optimized directional contourlet transform was described by Tamilarasi and Palanisamy in [5]. The main idea of UEP for ROI coded images over fading channels [6] is UEP scheme investigated for highly error sensitive ROI coded JPEG 2000 images transmitted over uncorrelated flat Rayleigh fading channels.

This article presents a new method of unequal error protection for region of interest with embedded zerotree wavelet algorithm. The main idea of our method is unequal error protection of image information with defined ROI for transmission over discrete channel with noise by using the EZW algorithm and the block coding techniques. A similar methodology exists [3, 6], but in this we will use RS codes [23] for error protection due to a cluster of errors. We will analyze the comparison of the unequal error protection (UEP) of image transmission (with defined ROI) with different error protection of symbols and the equal error protection (EEP) of image transmission (without defined ROI) over noisy channel.

The paper is organized as follows. First, basic information about ROI and UEP will be described in Section II. Basis of EZW will be mentioned briefly in Section III. In Section IV we will describe our method of UEP for ROI with EZW in detail. Then we will show some important results of the method in Section V. Finally conclusions will be drawn in the last section.

II. Region of Interest And Unequal Error Protection

A. Region of Interest (ROI)

ROI coding is important in applications where certain parts of an image are of a higher importance than the rest of the image. In these cases the ROI is encoded with higher quality than the background [20], [22]. Example applications include:

- Client/server applications where the server initially transmits a low quality/resolution version of an image. The client then selects an area of the image as a ROI and the server transmits only the data needed to refine (i.e., improve the spatial resolution/quality) of that ROI.
- Face images. When browsing a digital photograph album it is often the case that we are looking for, or most interest in, the people/faces in those photographs. Using an automated face detection algorithm the region(s) of an image that contain faces can be coded as ROIs and therefore stored with more accuracy than non-face sub-images [24].

B. Unequal error protection (UEP)

Masnick and Wolf first introduced the concept of unequal error protection in 1969. Their approach influenced different techniques of protection of codeword symbols, restricting the known facts to systematic codes [8].

The structure of codes with UEP differs fairly from the ordinary code. The ordinary codes are designed to obtain uniform distance distribution to provide a large minimum distance. The UEP codes have the codewords joined in clusters. In the case of UEP the bits of the code words are protected in order of importance. To that end, each subband is first quantized and the codewords are assigned according to certain rules. For each subband all bits that are in the same position in each codeword are joined together. The necessity for UEP arises in applications where the transmitted data is a coded signal such as speech, audio, image or video [7], [10], [19].

III. Embedded Zerotree Wavelet (EZW)

The EZW algorithm is considered the first really efficient wavelet coder. Its performance is based on the similarity between sub-bands and a successive-approximations scheme [1], [2], [9], [21].

The EZW algorithm is performed in several steps, with two fixed stages per step: the dominant pass and the subordinate pass. In Shapiro's paper [1] the description of the original EZW algorithm can be found. The EZW [2] codes each bit-plane successively to give an embedding property by horizontal scanning every bit-plane of the block’s during scanning the coefficients in both bit-by-bit and coefficient by coefficient manners. The EZW encoder is based on two important observations:

- Natural images in general have a low pass spectrum. When an image is wavelet transformed the energy in the subbands decreases as the scale decreases, so the wavelet coefficients will, average, be smaller in the higher subbands than in the lower subbands. This shows that progressive encoding is a very natural choice for compressing wavelet transformed images, since the higher subbands only add detail.
- Large wavelet coefficients are more important than smaller wavelet coefficients.

These two observations are exploited by the EZW encoding scheme by coding the coefficients in decreasing order, in several passes. For every pass a threshold is chosen against which all the coefficients are measured. If a wavelet coefficient is larger than the threshold it is encoded and removed from the image, if it is smaller it is left for the next pass. When all the wavelet coefficients have been visited the threshold is lowered and the image is scanned again to add more detail to the already encoded image. This process is repeated until all the wavelet coefficients have been encoded completely or another criterion has been satisfied (maximum bit rate for instance). The trick is now to use the dependency between the wavelet coefficients across different scales to efficiently encode large parts of the image, which are below the current threshold. It is here where the zerotree enters.

A wavelet transform transforms a signal from the time domain to the joint time-scale domain. This means that the wavelet coefficients are two-dimensional. If we want to compress the transformed signal we have to code not only the coefficient values, but also their position in time. When the signal is an image then the position in time is better expressed as the position in space. After wavelet transforming an image we can represent it using trees because of the subsampling that is performed in the transform. A coefficient in a low subband can be thought of as having four descendants in the next higher subband as you can see in Fig. 1. The four descendants each also have four descendants in the next higher subband and we see a quad-tree emerge: every root has four leafs. In the figure, L and H represent the low pass and high pass filters.

A zerotree is a quad-tree of which all nodes are equal to or smaller than the root. The tree is coded with a single symbol and reconstructed by the decoder as a quad-tree filled with zeroes.

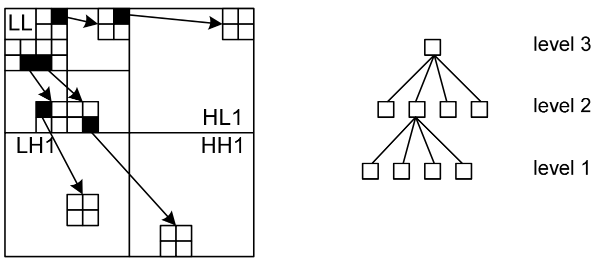

Fig. 1 The relations between wavelet coefficients in different subbands as quad-trees [2]

IV. Description of Proposed Method

The idea of the proposed method is to show the advantage of unequal error protection image information with defined ROI for the transmission over discrete channel with noise by using the EZW algorithm and the block coding technique against image transmission with the equal error protection. In this proposed system, image is divided into two parts (Fig. 2):

- ROI – Region of Interest,
- BG – Background.

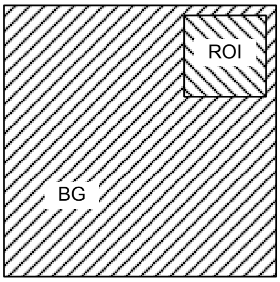

Fig. 2 Image with ROI and BG

In this analysis we will focus on the transmission of ROI defined in the image. The BG of the image is not important for this analysis.

In this method, at first the wavelet transform (WT) is applied to the gray-scaled image according to the size of the image. The following steps consist of generating wavelet coefficients and converting wavelet coefficients to the matrix format. We will choose suitable ROI of the image within image decomposition by WT. Subsequently, the compression technique EZW is implemented on wavelet coefficients. Two passes are used on compression by EZW. In the first pass, the dominant pass, the image is scanned and a symbol is outputted for every coefficient. The dominant pass contains an alphabet of symbols P, N, T, and Z. The second pass, the subordinate pass, is the refinement pass. This pass contains only bits. The main function of the subordinate pass is encoding of the size of coefficients. Encoding stops when final threshold value is achieved. Differential pulse code modulation (DPCM) and quantizer (Q) are implemented on LL image. Using the Huffman encoder (VLC – Variable Length Code), we obtain the bit stream, which will be coded by appropriate block encoder. In this step of the method, it is necessary to implement various error protections for the LL image, the ROI and the BG of the transmitted images. We will use the Reed-Solomon (RS) codes for protection of information bytes. LL image and the region of interest with the more important bytes (MIB) will be for image transmission ensured with stronger RS codes (Code 1 and 2) than the background with the less important bytes (LIB).

The RS codes utilized here are block based error correcting codes and are widely used for channel coding. The RS codes correct the symbol (or byte) error and not the bit error; length in terms of symbols. This is advantage of our proposed method due to existence of a cluster of errors. In this case one symbol equals eight bits. The block diagram of the proposed system is shown in Fig. 3.

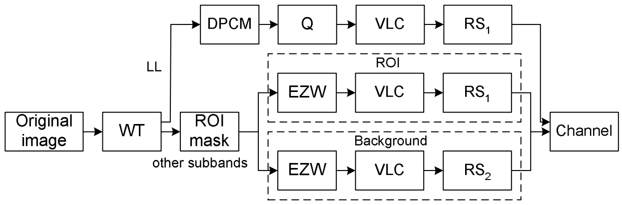

Fig. 3 Block diagram of proposed system

We will compare our results with the image transmission with EEP by EZW without defined ROI.

V. Results

In this section we will examine at what level the symbol error rate (*SER*) can still transmit images through a channel with noise. The primary result of the analysis will be a comparison of the image transmission ability with defined ROI (UEP) and without defined ROI (EEP).

The obtained results are shown in a chart, depending of *PSNR* (Peak Signal – to – Noise Ratio) on *SER* (Symbol Error Rate). In this case, the symbol is equal to 8 bits. The following RS codes were selected for error control of images:

- C_1 – RS (254, 188); correcting maximum 33 errors,
- C_2 – RS (238, 188); correcting maximum 25 errors,
- C_3 – RS (214, 188); correcting maximum 13 errors,
- C_4 – RS (204, 188); correcting maximum 8 errors.

The number of chosen information bytes is 188, but for the image transmission we will use 187 bytes. One byte is intended for synchronization.

We will analyze the image "Lena" of size 512 x 512 pixels. We will use wavelet transform (WT) on the image with using wavelet bior 4.4 and three levels wavelet decomposition.

The original image "Lena" is shown in Fig. 4. The original image "Lena" with the draft of ROI is shown in Fig. 5. We will use the stronger RS code in order to ensure the LL image and the area defined as ROI. The image decomposition after wavelet transform with bior 4.4 wavelet is shown in Fig. 6.

Table 1 shows the numerical values of *SER* for codes C_1 – C_4. Table 2 shows the numerical values of *PSNR* for individual decoded images.

First, we define the relations necessary for our method. Peak signal – to – noise ratio (*PSNR*) is define as [19]

$$PSNR = 20 \cdot \log_{10}\left(\frac{MAX}{\sqrt{MSE}}\right) \tag{1}$$

where *MAX* is maximum possible pixel value of the image. For an *M* x *N* size image is the mean – square error (*MSE*) define as [19]

$$MSE = \frac{1}{M}\frac{1}{N}\sum_{m=1}^{M}\sum_{n=1}^{N}[x(m,n) - \hat{x}(m,n)]^2 \tag{2}$$

where $x(m,n)$ and $\hat{x}(m,n)$ represent the original and the reconstructed pixels, respectively.

TABLE I
CALCULATION OF *SER* FOR VARIOUS CODING TECHNIQUES

Codes	*SER*
C_1 – RS (254, 188)	0.1299
C_2 – RS (238, 188)	0.1050
C_3 – RS (214, 188)	0.0608
C_4 – RS (204, 188)	0.0392

TABLE II
CALCULATION OF *PSNR* FOR VARIOUS DECODED IMAGES

Image	*PSNR* [dB]
Fig. 8/a	29.86
Fig. 8/b	31.11
Fig. 8/c	25.97
Fig. 8/d	25.04

The main results are:

- Equal error protection (EEP). In this case, the whole image without using ROI is ensured by Code 3.
- Unequal error protection (UEP). In this case, the more important bytes (LL image and ROI) are ensured by Code 1 and 2, the less important bytes (BG) are ensured by Code 4.

In the case of EEP (without ROI), the whole image is protected by RS (214, 188). In the case of UEP of image transmission with defined ROI, the RS (254,188) code is implemented on MIB (LL image), the RS (238,188) on MIB (ROI) and the RS (204,188) code is implemented for area which contains LIB. In Fig. 7 curve 1 shows the image transmission without ROI (EEP). Reconstruction image can be transmitted if values of *PSNR* and *SER* are: *PSNR* = 29.86 dB, *SER* $\leq$ 0.0608. With regard to the curve 2, the image transmission with the ROI and LL image (UEP) is analyzes. The image can be transmitted if values of *PSNR* and *SER* are: *PSNR* = 31.11 dB with *SER* $\leq$ 0.0392, *PSNR* = 25.97 for 0.0392 < *SER* $\leq$ 0.1050 and *PSNR* = 25.04 dB for 0.1050 < *SER* $\leq$ 0.1299.

From Fig. 7 we can see that after protecting MIB with the strongest RS code, we have the ability to transfer images with these features in multiple noisy channels. The ROI and LL image with the higher importance of bytes will be transmitted even when the channel error rate is higher. For our analysis, we were only dealing with a particular part of the image defined as ROI. After decoding, the BG becomes uninteresting to us as the main information is in the ROI and LL image. In our proposed method of the UEP for ROI with EZW algorithm, the transmitted image achieved better results in comparison with the transmitted image with EEP (without using ROI). With regard to the proposed method, we achieved gain of 95.64 % utilization of bandwidth in comparison with EEP of the image transmission. Fig. 8 represents decoded images "Lena" corresponding to various *SER*.


Fig. 4 Original image "Lena"


Fig. 5 Original image "Lena" with draft of ROI

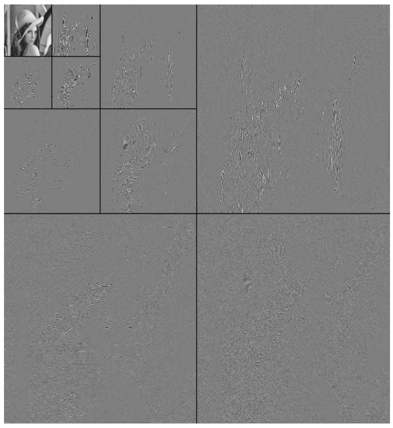
Fig. 6 Image "Lena" with three levels of decomposition

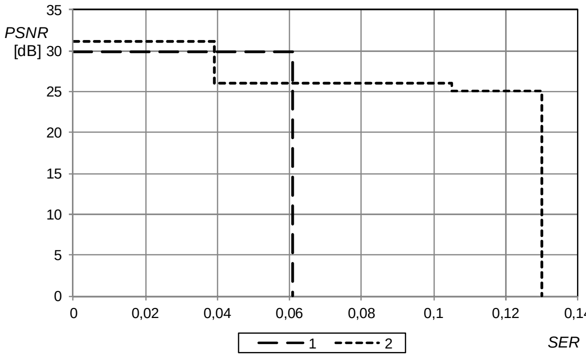

Fig. 7 Dependence of *PSNR* on *SER* for image "Lena":
1 – EEC without ROI (Fig. 8/a); Image after decoded where the RS (214,188) code is implemented for the image with EEC. For $SER \leq 0.0608$ can be transmitted reconstruction image with EEC. (0.398 bpp)
2 – UEC with ROI (Fig. 8/b, c, d); Image after decoded where the RS (254,188) code is implemented on MIB (LL image), the RS (238,188) on ROI and the RS (204,188) code for part of the image which contains LIB. For $SER \leq 0.1299$ can be transmitted reconstruction images with UEC with different values of *PSNR*. (0.414 bpp)

(a)

(b)

(c)

(d)

Fig. 8 Results on the test image "Lena" 512 x 512:
(a) image after decoding with EEC (without ROI) using RS (214,188) (0.398 bpp, $PSNR = 29.86$ dB, $SER \leq 0.0608$);
(b) image after decoding with using UEC for MIB (LL image) using RS (254,188), for MIB (ROI) using RS (238,188) and LIB using RS (204,188) (0.414 bpp, $PSNR = 31.11$ dB, $SER \leq 0.0392$);
(c) image after decoding with using UEC for MIB (LL image) using RS (254,188), for MIB (ROI) using RS (238,188) and LIB using RS (204,188) (0.414 bpp, $PSNR = 25.97$ dB, $0.0392 < SER \leq 0.1050$);
(d) image after decoding with using UEC for MIB (LL image) using RS (254,188), for MIB (ROI) using RS (238,188) and LIB using RS (204,188) (0.414 bpp, $PSNR = 25.04$ dB, $0.1050 < SER \leq 0.1299$);

That leads to the important conclusion that in the case of transmission of the image information with some more important parts for us, it is advantageous to use UEP for individual parts of image by using EZW and RS codes.

VI. Conclusion

In this manuscript a new method of unequal error protection for ROI with EZW was presented. Main idea of method is UEP image information for transmission over discrete channel with noise by using EZW algorithm and RS codes. We were analyzing the image "Lena" of size 512 x 512 pixels. In our analysis we were focused on the transmission of area defined as ROI in the image. LL image, the ROI and the BG are ensured by different RS codes.

Our results are compared with EEP of image transmission. In the case of transmission of the image information with some more important parts, it is advantageous to use unequal error protection for individual parts of image by using EZW and RS codes by means of described method.

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REFERENCES

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

[2] V. S. Shingate, T. R. Sontakke and S. N. Talbar, "Still Image Compression using Embedded Zerotree Wavelet Encoding," *International Journal of Computer Science & Communication*, vol. 1, no. 1, pp. 21-24, 2010.

[3] D. Vijendra Babu and N. R. Alamelu, "Wavelet Based Medical Image Compression Using ROI EZW," *International Journal of Recent Trends in Enginnering*, vol. 1, no. 3, pp. 97-100, 2009.

[4] T. M. P. Rajkumar and M. V. Latte, "ROI Based Encoding of Medical Images: An Effective Scheme Using Lifting Wavelets and SPIHT for Telemedicine," *International Journal of Computer Theory and Engineering*, vol. 3, no. 3, pp. 338-346, 2011.

[5] M. Tamilarasi and V. Palanisamy, "Fuzzy Based Image Compression on ROI using Optimized Directional Contourlet Transform," *International Journal of Recent Trends in Enginnering*, vol. 2, no. 5, pp. 217-221, 2009.

[6] Y. Yatawara, M. Caldera, T. M. Kusuma and H.-J. Zepernick, "Unequal Error Protection for ROI Coded Images over Fading Channels," *Systems Communications ICW'05*, pp. 111-115, 2005.

[7] M. H. Le and R. Liyana-Pathirana, "Unequal Error Protection Codes for Wavelet Image Transmission over W-CDMA, AWGN and Rayleigh Fading Channels," *10th International Conference on Telecommunications (ICT 2003)*, vol. 2, pp. 1140 – 1146, 2003.

[8] B. Masnick and J. Wolf, "On Linear Unequal Error Protection Codes," *IEEE Trans, Inform, Theory*, vol. IT-13, pp. 600 – 607, 1967.

[9] C. Chapman, S. Sanei, R. Dilmaghani, and F. Said, "Progressive transmission of medical images using embedded Zerotree wavelet encoding," *Proceedings of IEEE International Workshop on Biomedical Circuits and Systems (BioCAS '04)*, pp. S3.3-9–S3.3-12, 2004.

[10] J. L. Lo, S. Sanei and K. Nazarpour, "An Adaptive Source – Channel Coding with Feedback for Progressive Transmission of Medical Images," *International Journal of Telemedicine and Applications*, vol. 2009, no. 519417, pp. 1 – 12, 2009.

[11] L. Liu and G. A. Fan, "New JPEG 2000 Region-of-Interest Image Coding Method: Partial Significant Bitplanes Shift," *IEEE Signal Processing Letters*, vol. 10, no. 2, pp. 35-38, 2003.

[12] Z. Wang and A. C. Bovic, "Bitplane-by-Bitplane Shift (BbBShift) - A Suggestion for JPEG 2000 Region of Interest Coding," *IEEE Signal Processing Letters*, vol. 9, no. 5, pp. 160-162, 2002.

[13] F. Idris and F. Atef, "An Efficient Method for Region of Interest Coding in JPEG 2000," *5th WSEAS International Conference on Signal Processing*, pp. 65-69, 2006.

[14] M. J. T. Smith and S. L. Eddins, "Analysis/Synthesis Techniques for Subband Image Coding," *IEEE Trans. Acoust., Speech, and Signal Proc.*, vol. 38, no. 8, pp. 1446 – 1456, 1990.

[15] M. Antonini, M. Barlaud, P. Mathieu, and I. Daubechies, "Image coding using wavelet transform," *IEEE Transactions of Image Processing*, vol. 1, no. 2, pp. 205–220, 1992.

[16] F. Etemadi, and H. Jafarkhani, "An Efficient Progressive Bitstream Transmission System for Hybrid Channels With Memory," *IEEE Trans. Multimedia Sig. Proc.*, vol. 8, no. 6, pp. 1291-1298, 2006.

[17] V. M. Stankovic, R. Hamzaoui, Y. Charfi, and X. Zixiang, "Realtime unequal error protection algorithms for progressive image transmission." *IEEE J. Sel. Areas Commun.*, vol. 21, no. 10, pp. 1526 – 1535, 2006.

[18] W. Song, C. Kim and S. Lee, "Progressive compression and transmission of PointTexture images," *J. Visual Comm. Image Rep.*, vol. 17, no. 5, pp. 1090-1107, 2006.

[19] P. H. Westerink, "Subband coding of images," *PhD thesis*, Technische Universiteit Delft, 1989.

[20] H-S. Kong, A. Vetro, T. Hata and N. Kuwahara, "Fast Region-of-Interest Transcoding for JPEG 2000 Images," *IEEE International Symposium on Circuits and Systems (ISCAS)*, vol. 2, pp. 952-955, 2005.

[21] J. Oliver and M. P. Malumbres, "An Implementation of the EZW Algorithm," *Universidad Jaume I (SNRFAI 2001)*, pp. 37-42, 2001.

[22] A. P. Bradley and F. W. M. Stentiford, "JPEG 2000 and Region of Interest Coding," *Digital Image Computing Techniques and Applications (DICTA)*, vol. 303-308, 2002.

[23] T. K. Moon, *Error correction coding – Mathematical methods and algorithm*. New Jersey: John Wiley & Sons, 2005, ch. 6.

[24] M. Oravec, J. Pavlovičová, J. Mazanec, Ľ. Omelina, M. Féder and J. Ban, "Efficiency of Recognition Methods for Single Sample per Person Based Face Recognition," *Reviews, Refinements and New Ideas in Face Recognition (InTech)*, pp. 181-206, 2011.

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