Unequal Error Protection of Facial Features for Personal ID Images Coding

T. Hirner and J. Polec

Abstract**—**This paper presents an approach for an unequal error protection of facial features of personal ID images coding. We consider unequal error protection (UEP) strategies for the efficient progressive transmission of embedded image codes over noisy channels. This new method is based on the progressive image compression embedded zerotree wavelet (EZW) algorithm and UEP technique with defined region of interest (ROI). In this case is ROI equal facial features within personal ID image. 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 and encoding LL band separately. 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 proposed unequal error protection of image transmission has shown to be more appropriate to low bit rate applications, producing better quality output for ROI of the compresses image. The experimental results verify effectiveness of the design. The results of our method demonstrate the comparison of the UEP of image transmission with defined ROI with facial features and the equal error protection (EEP) over additive white gaussian noise (AWGN) channel.

Keywords**—**Embedded zerotree wavelet (EZW), equal error protection (EEP), facial features, personal ID images, region of interest (ROI), unequal error protection (UEP)

I. INTRODUCTION

DUE to the increasing traffic caused by multimedia information and digitized form of representation of images; image compression has become a necessity. New algorithms for image compression based on wavelets have been developed. These methods have resulted in practical advances such as: superior low-bit rate performance, bit-level compression, lossless and lossy compression, progressive transmission by pixel, accuracy and resolution, region of interest coding and others. Uncompressed multimedia data requires considerable storage capacity and transmission bandwidth. Demand for data storage capacity and data transmission bandwidth continues to outstrip the capabilities of available technologies. The recent growth of data intensive multimedia-based applications have not only the need for more efficient ways to encode signals and images but have made compression of such signals central to storage and communication technology. The above information clearly illustrates the need for sufficient storage space, large transmission bandwidth and long transmission time for image data. The rapid growth of multimedia communication has resulted also in a demand for robust transmission of compressed images. The challenge of robust transmission is to maximize the received image quality. However, for highly compressed images, it would be beneficial that regions of interest (ROI) are prioritized for interpretability. The functionality of ROI is important in applications where certain parts of the image are of higher importance than others [8], [10].

The early wavelet-based image coders [3], [33] 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, in 1993 Shapiro [1] built an elegant algorithm for entropy encoding called Embedded Zerotree Wavelet (EZW) algorithm. The zerotree is based on the hypothesis that if a wavelet coefficient at a coarse scale is insignificant with respect to a given threshold *T*, then all wavelet coefficients of the same orientation in the same spatial location at a finer scales are likely to be insignificant with respect to *T*. Many insignificant coefficients at higher frequency subbands can be discarded. This results in bits that are generated in order of importance, yielding a fully embedded code.

The areas of ROI and EZW have already been described in a number of sources. Recently, much attention has been paid to the 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 [14], [31], [32]. An image coding scheme in conjunction with automatic ROI identification is presented in [22]. Knowledge based hierarchical ROI detection method is proposed in [23]. An approach for ROI detection for the financial document images is presented in [24]. In this method, the ROIs are defined and classified into three types; filled information, stamps and seals, and handwritings.

The concept of image coding utilizing discrete wavelet transform (DWT) and EZW has been initially proposed in [1] and various methods have been developed based on this idea [3]–[6]. In [3], 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

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transform is particularly well suited for progressive transmission. In [4], the concepts of DWT, EZW, progressive image transmission, and ROI have been utilized. In [5], a method for progressive image transmission using EZW is presented where a number of constraints are imposed to provide variable bitrates for each frequency band. The authors in [6] have developed strategies to exploit the wavelet coefficients in different subbands for designing different vector quantization (VQ) coding to achieve a fast and efficient progressive transmission.

The concept for transmission of medical images is described in [2], [7], [11], [12]. Transmission of medical images by using EZW and DWT was described in [2]. A novel adaptive source-channel coding with feedback for progressive transmission of medical images was presented in [7]. In [11] the medical image is segmented and compressed by wavelet method to increase the compression ratio and to store in a less space. The aim of [12] was to present a novel platform for advanced transmission of medical image and video, introducing context awareness in telemedicine systems. An evaluation platform has been developed based on scalable wavelet compression with ROI support for images and adaptive H.264 coding for video.

Special area of ROI coding methods are described in [13], [14]. Preferential encoding of the ROI is one of the unique features of JPEG2000 that makes it suitable for applications such as imaging over error prone channels. In the sequel, the two methods for ROI coding defined in the standard, general scaling based (GSB) and maximum shift (MAXShift) method [13]. Newer methods of ROI coding such as bitplane-by-bitplane shift (BbBShift) method, generalized bitplane-by-bitplane shift (GBbBShift) method, Partial Significant Bitplanes Shift (PSBShift) method or Most Significant Bitplane Shift (MSBShift) method were presented in [14]–[17].

Description of unequal error protection performances in images transmission over time-varying channels was presented in [18]. In [19] was described unequal error protection multilevel codes and hierarchical modulation for multimedia transmission. The UEP area in conjunction with fractal image codes was described in [20]. Fuzzy based image compression on ROI using optimized directional contourlet transform was described in [26]. The main idea for method of UEP for ROI coded images over fading channels [27] is UEP scheme investigated for highly error sensitive ROI coded JPEG 2000 images transmitted over uncorrelated flat Rayleigh fading channels. Unequal Error Protection Codes for Wavelet Image Transmission over W-CDMA, AWGN and Rayleigh Fading Channels was in detail described in [28].

This article presents a new method for UEP of facial features for personal ID images coding. The main idea of our method is unequal error protection of image information with defined ROI with facial features for transmission over AWGN channel. A similar methodology exists [7], [27] but in this we will use different error protection principle by using wavelet decomposition, DPCM, EZW algorithm and RS codes [21] for error protection which corrects the symbol error, but not only the bit error. In our case one symbol equals eight bits. We will analyze the comparison of the UEP of image transmission with defined ROI (facial features) with different error protection of symbols and the EEP of image transmission over AWGN channel. In addition to UEP approach the error concealment techniques [35] could be used to increase further the robustness of overall approach.

The paper is organized as follows. First, basic information about UEP will be described in Section II. Section III describes general concept of ROI technique. Advantages of using RS codes will be presented in Section IV. Basis of EZW will be mentioned briefly in Section V. In Section VI we will describe our method for unequal error control of facial features for personal ID images coding in detail. Then we will show important results of the method in Section VII. Finally conclusions will be drawn in the last section.

II. Unequal Error Protection

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 [29].

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 [28], [30], [34].

III. Region of Interest

ROI technique in the image is important in applications where certain parts of an image are of a higher importance than the rest of the image (background). ROI is encoded with higher quality than the background [8], [10]. Implementations of ROI concept include:

- Digital photographs (personal ID images, face images)
- Satellite images and aerial photographs satellite images include images of the Earth or other planets taken from satellites - typical examples include buildings, tanks, and planes on military bases)
- Medical images (images of the human body or some parts of human body)
- Document images (the ROIs in this class of images may be printed text, handwritten text, and stamps)

IV. Reed Solomon Codes

Reed Solomon (RS) codes [21] are a special case of BCH codes. An (*n*, *k*) RS code takes a group of *k* data symbols and generates *n*-*k* parity symbols; *n* is the codeword size, measured in symbols. The error correcting capability of the code is directly related to the number of symbols, which differ between any two different codewords. The RS codes provide a wide range of codes with different code lengths and error correction capabilities, from which the most appropriate codes may be selected. They are simpler to decode than turbo or convolutional codes. The RS codes correct the symbol error and not the bit error. This is advantage of our proposed method due to existence of a cluster of errors.

V. 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], [4], [9], [25].

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 [25] 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.
- 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.

The main advantage of this encoding is that the encoder can terminate the encoding at any point, thereby allowing a target bit rate to be met exactly. Similarly, the decoder can also stop decoding at any point resulting in the image that would have been produced at the rate of the truncated bit stream. The algorithm produces excellent results without any pre-stored tables or codebooks, training, or prior knowledge of the image source.

VI. Description of Proposed Method

The idea of the proposed method of UEP of facial features for personal ID images coding is to show the advantage of unequal error protection image information with defined ROI (facial features) for the transmission over AWGN channel by using wavelet decomposition, DPCM, 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: ROI (Region of Interest – facial features) and BG (Background). Unequal error protection of image is provided by different coding techniques and encoding LL band separately (L represents the low pass filter).

In our method we will focus on the transmission of facial features defined in the image. Defined facial features in the personal ID image are the eyes, nose and mouth. The BG of the image is not important for this analysis. The block diagram of the proposed system is shown in Fig. 1.

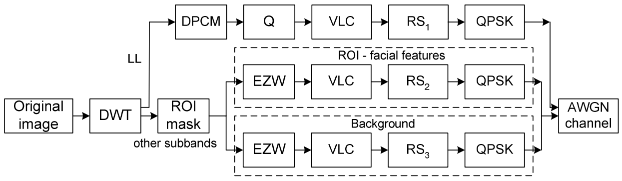

Fig. 1 Block diagram of proposed system

In this method, at first the discrete wavelet transform (DWT) 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 using DWT. Suitable ROI for our method is facial features (eyes, nose and mouth). 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 (facial features) and the BG of the transmitted images. We will use the RS codes for protection of information bytes. LL image and the region of interest with the more important bytes will be for image transmission ensured with stronger RS codes (Code 1 and 2) than the background with the less important bytes.

After protection of information bytes by RS code we will implement QPSK modulation on individual parts of image that will be transmitted over AWGN channel.

We will compare our results with the image transmission with EEP by EZW without defined facial features of image.

VII. Results

The primary result of the analysis will be a comparison of the image transmission ability with UEP and EEP. The obtained results are shown in a chart, depending of *PSNR* (Peak Signal – to – Noise Ratio) on E_b/N_0 (the energy per bit to noise power spectral density ratio).

The following RS codes were selected for error control of images:

- C_1 – RS (254, 188); correcting maximum 33 errors,
- C_2 – RS (246, 188); correcting maximum 29 errors,
- C_3 – RS (210, 188); correcting maximum 11 errors,
- C_4 – RS (202, 188); correcting maximum 7 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 "Tiffany" of size 512 x 512 pixels. We will use discrete wavelet transform on the image with using wavelet bior 4.4 and three levels wavelet decomposition.

The original image "Tiffany" is shown in Fig. 2. The original image "Tiffany" with the draft of ROI (facial features) is shown in Fig. 3. Individual facial features (eyes, nose, and mouth) are shown in Fig. 4. The image decomposition after wavelet transform with bior 4.4 wavelet is shown in Fig. 5.

The main results are in two types of error protection: equal error protection and unequal error protection. We will use the stronger RS code in order to ensure the LL image and the area defined as ROI with facial features. In the case of EEP, the whole image without using ROI (facial features) is ensured by Code 3. For UEP, the more important bytes (LL image and ROI with facial features) are ensured by Code 1 and 2, the less important bytes (BG) are ensured by Code 4.

In the case of EEP, the whole image is protected by RS (210, 188). In the case of UEP of image transmission with defined ROI with facial features, the RS (254,188) code is implemented on MIB (LL image), the RS (246,188) on MIB (ROI with facial features) and the RS (202,188) code is implemented for area which contains LIB. Decoded images "Tiffany" corresponding to various *PSNR* is shown in Fig. 6. Table I shows the numerical values for individual decoded images.

TABLE I
Calculation of *PSNR* for Various Decoded Images

Image	*PSNR* [dB]
Fig. 6/a	30.44
Fig. 6/b	28.87
Fig. 6/c	26.82
Fig. 6/d	17.23
Fig. 6/e	16.94

Fig. 2 Original image "Tiffany"

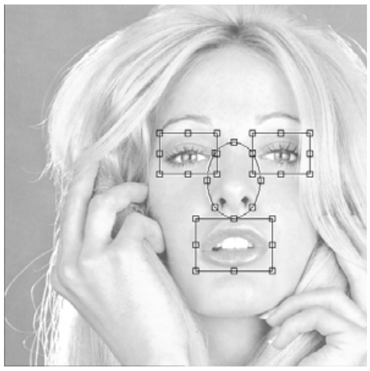

Fig. 3 Original image "Tiffany" with draft of ROI

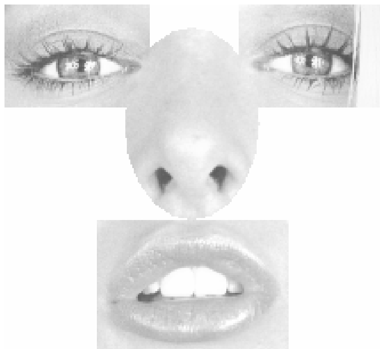

Fig. 4 ROI – facial features (eyes, nose, mouth)

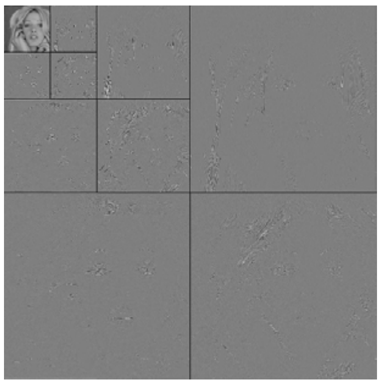

Fig. 5 Image "Tiffany" with three levels of decomposition

(a)

(b)

(c)

(d)

(e)

Fig. 6 Results on the test image “Tiffany” 512 x 512:
(a) image after decoding with EEC using RS (210,188) (0.400 bpp, $PSNR$ = 30.44 dB, $E_b/N_0 \geq 3.9$)
(b) image after decoding with using UEC for MIB (LL image) using RS (254,188), for MIB (ROI – facial features) using RS (246,188) and LIB using RS (202,188) (0.394 bpp, $PSNR$ = 28.87 dB, $E_b/N_0 \geq 5$)
(c) image after decoding with using UEC for MIB (LL image) using RS (254,188), for MIB (ROI – facial features) using RS (246,188) and LIB using RS (202,188) (0.394 bpp, $PSNR$ = 26.82 dB, $3 \leq E_b/N_0 < 5$)
(d) image after decoding with using UEC for MIB (LL image) using RS (254,188), for MIB (ROI – facial features) using RS (246,188) and LIB using RS (202,188) (0.394 bpp, $PSNR$ = 17.23 dB, $E_b/N_0 = 2.5$)
(e) image after decoding with using UEC for MIB (LL image) using RS (254,188), for MIB (ROI – facial features) using RS (246,188) and LIB using RS (202,188) (0.394 bpp, $PSNR$ = 16.94 dB, $E_b/N_0 = 2$)

In Fig. 7 curve 1 shows the image transmission without ROI (EEP). Reconstruction image can be transmitted if values of $PSNR$ and E_b/N_0 are: $PSNR$ = 30.44 dB, $E_b/N_0 \geq 3.9$. 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 E_b/N_0 are: $PSNR$ = 28.87 dB with $E_b/N_0 \geq 5$, $PSNR$ = 26.82 for $3 \leq E_b/N_0 < 5$, $PSNR$ = 17.23 dB for $E_b/N_0 = 2.5$ and $PSNR$ = 16.94 for $E_b/N_0 = 2$. In Fig. 7 curve 3 shows the image transmission without error protection technique. This type of reconstruction image can be transmitted if $PSNR$ = 31.39 dB for $E_b/N_0 \geq 9.5$.

From Fig. 7 we can see that after protecting MIB (LL image and ROI with facial features) with the strongest RS code, we have the ability to transfer images with these features in multiple noisy AWGN channel. The ROI with facial features 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 facial features of the image defined as ROI. After decoding, the BG becomes uninteresting to us as the main information is in the ROI with facial features and LL image.

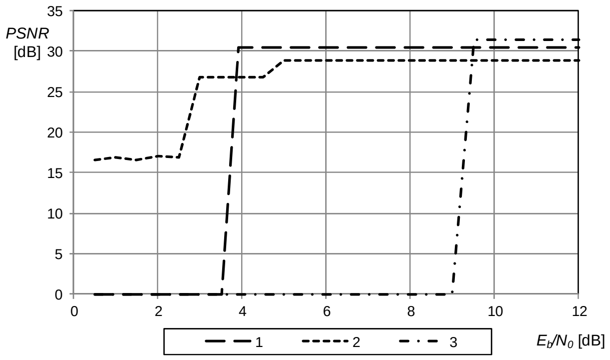

Fig. 7 Dependence of *PSNR* on E_b/N_0 for image "Tiffany":
1 – EEC without ROI – facial features (Fig. 6 (a)); Image after decoded where the RS (210,188) code is implemented for the image with EEC. For $E_b/N_0 \geq 3.9$ can be transmitted reconstruction image with EEC (0.400 bpp)
2 – UEC with ROI – facial features (Fig. 6 (b), (c), (d), (e)); Image after decoded where the RS (254,188) code is implemented on MIB (LL image), the RS (246,188) on MIB (ROI – facial features) and the RS (202,188) code for part of the image which contains LIB. For $E_b/N_0 \geq 2.5$ can be transmitted reconstruction personal ID images with defined ROI (facial features) with different values of *PSNR* (0.394 bpp)
3 – Uncoded image; For $E_b/N_0 \geq 9.5$ can be transmitted reconstruction image without coding (0.406 bpp)

In our proposed method for unequal error protection of facial features for personal ID images coding, the transmitted image achieved better results in comparison with the transmitted image with EEP.

VIII. Conclusion

In this paper a new method for unequal error protection of facial features for personal ID images coding was presented. Main idea of method is UEP image information for transmission over AWGN channel by using wavelet decomposition, DPCM, EZW algorithm and the block coding technique. The image "Tiffany" of size 512 x 512 pixels was analyzed. In our analysis we were focused on the transmission of facial features of 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 facial features as a more important part, it is advantageous to use unequal error protection with our proposed method.

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