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LOW BITRATE HYBRID SECURED IMAGE COMPRESSION FOR WIRELESS IMAGE SENSOR NETWORK

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ABSTRACT

Wireless image sensor networks are capable of sensing, processing and transmitting the visual data along with the scalar data and have attained wide attention in sensitive applications such as visual surveillance, habitat monitoring, and ubiquitous computing. The sensor nodes in the network are resource constrained in nature. Since the image data are huge always high computational cost and energy budget are levied on the sensor nodes. The compression standards JPEG and JPEG 2000 are not feasible as they involve complex computations. To stretch out the life span of these nodes, it is required to have low complex and low bitrate image compression techniques exclusively designed for this platform. The complicated scenario of wireless sensor network in processing and transmitting image data has been addressed by a low complex hybrid secured image compression technique using discrete wavelet transform and Bin discrete cosine transformation.

Keywords: Discrete wavelet transform, Binary discrete cosine transform, Rubik's cube, Encryption, Wireless image sensor networks.

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INTRODUCTION

Modern advancements in electro-mechanical systems and the inexpensive complementary metal-oxide semiconductor cameras transfigured the traditional wireless sensor networks into wireless image sensor networks (WISN) and are capable of sensing, processing and transmitting still images, and videos. The typical WISN architecture is as shown in Fig. 1. The WISN is made up of a number of sensor nodes scattered over the geographic region and are wirelessly connected. Each node with visual ability (camera attached) is called as visual senor node.

These nodes will transmit the data to base station or sink node via intermediate nodes in multi-hop fashion. These nodes have light weight processors, low memory in order of several tens of KBs, low communication bandwidth and are mostly battery powered [1]. The life time of the nodes is determined by the computational energy and communication energy expenditures levied on them. Radio transceivers are power hunger component in any wireless device. Moreover, the computational cost is high for manipulating image data than the scalar data. Hence, it is obvious to focus on low complex energy efficient low bitrate image compression technique to have active live nodes in the network for a long time. Image data are more sensitive can reveal more information if tampered [2]. Complex security algorithms will be very expensive which is not affordable by the sensor nodes. Hence, light weight security algorithms are to be incorporated. The proposed compression algorithm follows a four step chained process as transformation - encryption- quantization - coding. The proposed system uses hybrid approach of transformation.

The paper is organized as follows Section II briefs related work and their short comings. Section III describes the proposed hybrid secured image compression. Section IV discusses about experimental results and analysis, and Section V will conclude the paper with proposed future work.

RELATED WORK

Lee *et al*. have proposed an adaptive JPEG compression for energy efficient image communication using range analysis but used complex discrete cosine transformation (DCT) which consumes more energy [3]. Lecuire *et al*. used a zonal based DCT approach for image communication over WISN [4]. Nasri *et al.* implemented a discrete wavelet transform (DWT) based image compression by skipping the high pass bands of two-dimensional image decomposition [5]. The complex floating point operations were being replaced by addition and shift operations and termed as integer transforms. Several integer DCTs were found in the literature, namely, Loeffler-Ligtenberg-Moschytz, Cordic loeffler, and Chen's factorization. Duran-Faundez *et al*. implemented a tiny block image coding for WISN based on adaptive pixel removal technique and Torus-automorphism pixel shuffling technique for robustness against packet loss circumstances [6]. Kaddachi *et al*. suggested a hardware based implementation of DCT on FPGA based on Cordic-loeffler DCT which uses 38 addition operations and 16 shift operations for an 8-point one-dimensional transform [7]. Furthermore, Pham *et al*. used the same version of DCT as it offers high quality image at a higher computational cost [8]. Rein *et al*. introduced an integer transform in the wavelet domain as line based DWT for low memory implementation [9]. There is a wealth of literature available for image communication over wireless sensor networks but they are either based on pure DCT or pure DWT. To combine the advantages of these transforms, the proposed system uses the hybrid approach of DWT and DCT. As like compression, there is more number of image encryption algorithms found in the recent literature. They are mostly based on chaotic and logistic maps, pixel swapping, pixel scrambling schemes, etc. [10-15]. Rubik's cube scrambling has been adapted by many researchers [11,15]. Many researchers working on "encryption while compression" for reducing the complexity rather than independent encryption. Rubik's cube pixel scrambling technique allows block based approach as it can be easily integrated with DCT stage.

HYBRID SECURED IMAGE COMPRESSION

The proposed system architecture is as shown in Fig. 2. The DWT had played lead role in JPEG 2000 because of its long list of advantages. This transform retains both space and frequency domain information of the original signal and made JPEG 2000 standard suitable for low bitrates. The DCT was used in JPEG. Due to its null DC leakage property, energy compaction and low memory implementation of tiling style made JPEG unbeatable by any other standard. But for resource limited platforms like WISN JPEG and JPEG 2000 cannot be easily adaptable. Hence to combine the merits of both DWT and DCT, the proposed system uses hybrid transform based DWT and DCT. The system first applies two-dimensional DWT on the image using Daubechies wavelet filters. This decomposes the image into four different sub bands, namely, LL, LH, HL, and HH. The LL band contains approximated, coarse and smoothened version of the image. HL band clutches vertical details, LH band holds horizontal details and HH diagonal details of the image as shown in Fig. 3.

The LL band contains most significant data content, which is sufficient enough to recognize the image. Hence, the proposed method uses only the approximated band (LL) for computation and transmission [16]. A compression ratio of 75% is achieved by omitting the other bands of the wavelet decomposition. BinDCT is a multiplier free fast integer version of true DCT based on Chen's factorization [17]. In BinDCT the complex floating point multiplication operations of the cosine transform are replaced by addition and binary shift operations. BinDCT offers several configurations from BinDCT-C1 to BinDCT-C9 with decreased computational cost and increased the image distortion but sufficient enough for visual perception. Since the life time of the sensor node is more important in WISN than the high quality image transmission, BinDCT-C8 has been chosen. The BinDCT-C8 version uses only as low as five shifters and 24 adders for an 8-point one-dimensional transform. That is 384 addition operations and 80 shift operations for a two-dimensional 8×8 block transform.

Encryption

Next step of the proposed system is encryption, here pixel scrambling is done using Rubik's Cube scrambling technique [14]. The Rubik's cube pixel scrambling uses two randomly generated encryption keys of size equal to the size of a transform block, which is 8. One key is for rowwise scrambling, and the other is used for columnwise pixel scrambling. They will not manipulate anything on the data content, merely pixel positions are interchanged and the image is obfuscated, so that if the image is tampered, it will not convey any meaning.

QUANTIZATION

Next step of the compression chain is quantization. The quantization step is to reduce the insignificant components of the transformed coefficients. The transformed and trans-positioned pixel values are quantized using binary shift operations instead of floating point division. In the proposed system two types of quantization scheme are used. One is based on JPEG quantization table, and the other is based on uniform quantization [18]. In JPEG based quantization, the values in the original JPEG luminance quantization table are rounded to their near powers of two values as shown in Fig. 4. Division of X by two is equivalent to one bit right shift of X in binary. Hence, to divide a coefficient X by 16 (2^4) is done by four-bit binary right shift of X. In uniform quantization, a scalar value Q in powers of two is chosen according to the bitrate requirement. For low bitrate higher value of Q is chosen with reduced quality and *vice versa*.

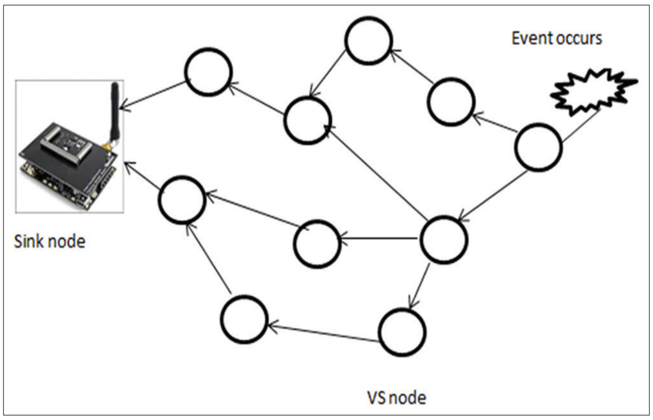

Fig. 1: Wireless image sensor networks architecture

Entropy coding

The final step of the compression chain is entropy coding. Low complex entropy coder well suggested in literature for WISN is listless or dictionary less coder called Golomb-Rice (G-R) code [19]. Zhao *et al.* presented a modified version of GR code with zero tree ordering [20]. Zero tree ordering is effective when more zero coefficients are present. In the proposed work zero tree ordering is eliminated as the system has considered only most significant LL band and hence complexity is still reduced. The G-R code is implemented as in Zhao *et al.* [20].

EXPERIMENTAL RESULTS AND PERFORMANCE ANALYSIS

The experimental results of test images all of size 512×512 of the proposed system are presented in Fig. 5 [21]. The result and performance analysis are twofold here, first the performance of image compression is analyzed and then the performance of encryption algorithm is done. The performance of any image compression algorithm is analyzed by distortion measure called peak signal to noise ratio (PSNR), bitrate and/or compression ratio. The performance of the security algorithm is assessed by a number of changing pixel rate (NPCR) and unified average changing intensity (UACI), where NPCR stands for the number of pixels change rate and UACI [22]. These two parameters are used to check robustness of the encryption system against differential attacks.

Mean square error (MSE) is aggregated squared difference between the original and the decompressed image. MSE is calculated using equation 1.

$$MSE=\frac{1}{mn}\sum_{p=1}^{m}\sum_{q=1}^{n}[I(p,q)-O(p,q)]^2 \quad (1)$$

Where m, n are the number of rows and columns, and I (p, q), O (p, q) represent pixel intensities of original and decompressed image, respectively.

PSNR: PSNR is defined as the degree of error relative to the peak value of the data and the mean squared error between the original and decompressed image. The peak value of the grey scale pixel is 255. The unit of PSNR is decibel (dB) and calculated using equation 2. The PSNR of the proposed system is good enough for recognition as shown in Fig. 5. The distortion analysis in terms of PSNR and achieved bitrate of the proposed system is presented in Table 1. The bitrate and PSNR of JPEG based quantization scheme and uniform quantization are almost similar. The Q value is chosen such that it matches with the other scheme. For decreased bitrate Q can be chosen as a big value.

$$PSNR=10\log_{10}\frac{y_{peak}^2}{MSE} \quad (2)$$

Bitrate: It is defined as the number of bits required to represent a pixel. It is measured in bits per pixel (BPP).

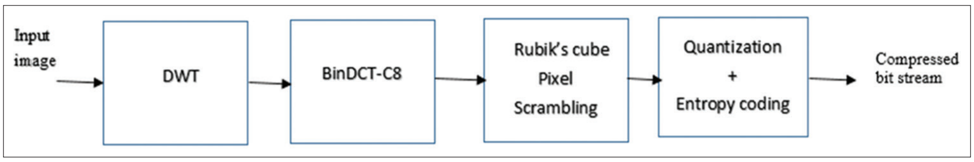

Fig. 2: Proposed system architecture

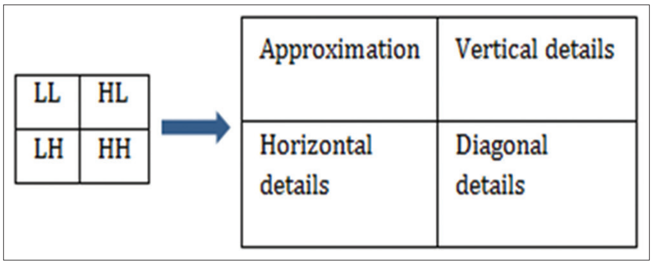

Fig. 3: Discrete wavelet transform subband decomposition

(a)

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

(b)

16	16	8	16	32	32	64	64
16	16	16	16	32	64	64	64
16	16	16	32	32	64	64	64
16	16	32	32	64	64	64	64
16	32	32	64	64	128	128	64
32	32	64	64	64	128	128	64
32	64	64	64	64	128	128	128
64	64	64	64	128	128	128	64

Fig. 4: (a) JPEG quantization table, (b) proposed JPEG based quantization table

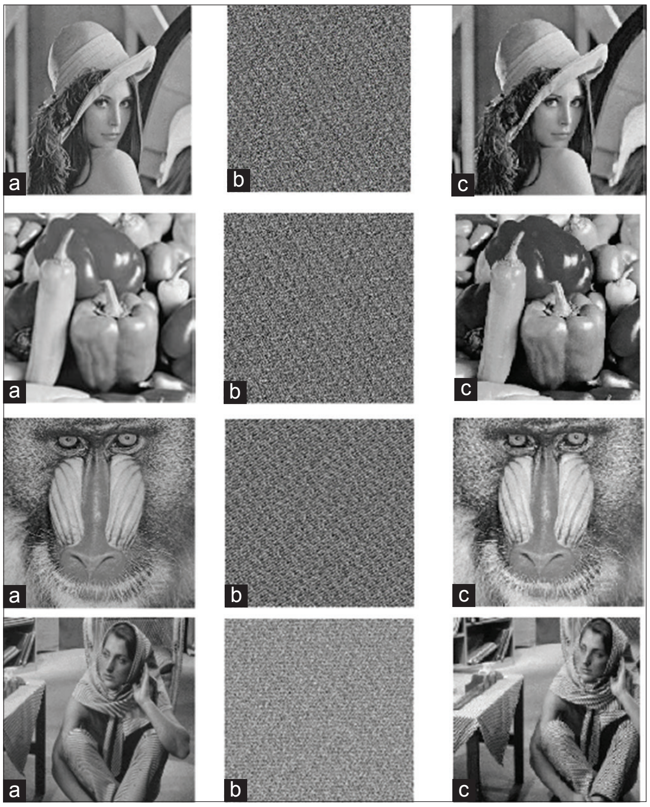

Fig. 5: Experimental results of test images, Lena, peppers, mandrill and Barbara of size 512×512, (a) original, (b) compressed-encrypted, and (c) decompressed-decrypted

NPCR: It is a parameter applied to check the robustness or sensitivity of the encryption algorithm. The rate of changing pixel intensities of the encrypted image when just one of the pixels is changed in original raw image. When one pixel is changed in the encrypted image, the encryption algorithm should offer a totally different encrypted image from the original image. It is calculated using equation 3.

$$NPCR = \sum_{i=1}^{m}\sum_{j=1}^{n} d(i,j) * \frac{100\%}{m*n} \quad (3)$$

Table 1: Experimental results of the proposed system

Image	JPEG quantization		Uniform quantization	
	Bitrate (bpp)	PSNR (dB)	Bitrate (bpp)	PSNR (dB)
Lena	0.85	31.57	0.89	31.56
Barbara	0.89	25.42	0.90	25.41
Baboon	1.08	27.58	1.09	27.27
Peppers	0.99	29.99	1.01	29.99

PSNR: Peak signal to noise ratio

Table 2: NPCR and UACI sensitivity analysis results

Test images	Lena	Baboon	Barbara	Peppers
NPCR (%)	99.53	99.13	99.26	99.87
UACI (%)	34.45	32.93	33.49	35.01

NCPR: Number of changing pixel rate, UACI: Unified average changing intensity

Where m, n are the number of rows and columns. The values of the matrix d is decided by the following condition, if I_{in} (i,j) = I_{enc} (i,j) then d (i,j) = 0 else d (i,j) = 1, where I_{in} is the input image and I_{enc} is the encrypted image.

UACI: It is a parameter to find the difference in average intensity between the input image intensity and obfuscated image intensity. Mathematical expression for UACI is as given in equation 4.

$$UACI = \left[\sum_{i=1}^{m}\sum_{j=1}^{n} \frac{|Iin(i,j)-Ienc(i,j)|}{y_{peak}}\right] * \frac{100\%}{m*n} \quad (4)$$

Where m, n are the number of rows and columns, where I_{in} is the input image, and I_{enc} is the encrypted image.

The sensitivity parameters NPCR percentage and UACI percentage of the proposed system is presented in Table 2. From the Table 2, it is inferred that the system is robust against differential attacks. The obtained values NPCR and UACI parameters are in the range as suggested by Ahmed *et al.* [20].

CONCLUSION

Thus, a low bitrate hybrid secured image compression algorithm has been presented suitable for WISN. It uses DWT and DCT based transforms in a hybrid fashion to combine the merits of both DWT and DCT based transforms. As part of security Rubik's cube pixel scrambling is incorporated along with compression. Low complexity G-R code is used for entropy coding along with both nonuniform and uniform quantization schemes and offered low bitrate of 1 BPP on average with acceptable visual quality (PSNR) values. The NPCR and UACI analysis revealed that the system is robust. Further, the future work will be simulating the system in target platform using Atmel's AVR Studio for energy consumption analysis and also to optimize the system to achieve a very low bitrate of <0.25BPP.

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