Analysis of Lossy Image Compression using CCSDS Standard Algorithm using Various Quantization Factor

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Abstract— Image data compression is process to remove the redundant and irrelevant information from the image so that only essential information can be represented using less number of bits to reduce the storage size, transmission bandwidth and transmission time requirements. With Increase in Resolution of images and size there is continuous need of powerful compression techniques that provide higher compression ratio with higher performance in terms of better Peak signal to Noise Ratio and low Maximum Absolute Error (MAE). Consultative Committee for Space Data System (CCSDS) which is consortium of leading space agencies has defined such powerful compression standard called CCDS "Image Data Compression”. It provides performance comparable to leading compression algorithms like JPEG2000 /SPIHT etc. This image compression standard is based on Discrete Wavelet Transform (DWT), low frequency DWT coefficient (DC-coefficient) quantization & Golomb-Rice coding and bit plane encoding of Higher frequency (AC) coefficients. An outcome is produced for encoding performed to the low frequency substance of the DWT translated image because the human visual system is more delicate to the low frequency segment and encoding is carried out just on low frequency contains that gives lossy compression but accomplished high compression ratio. In this paper analyse the image with different quantization factor and shows that how many quantization bits are possible in image of low frequency co-efficients and image visualization is available after reconstructing of image. Here in different images cheak with different quantization factor and cheak their compression parameter and image visualization.

Key words: CCSDS Standard Recommendation, Initial Coding Of DC Coefficients, Quntization Factor

I. INTRODUCTION

The increasing demand for multimedia content such as digital images and video has led to great interest in research into powerful compression techniques like JPEG-2000, CCSDS Image compression standard etc. The development of higher quality and less expensive image acquisition devices has produced steady increases in both image size and resolution, and a greater consequent for the design of efficient compression systems. Although storage capacity and transfer bandwidth has grown accordingly in recent years, many applications still require compression like satellite based acquisition and transmission of high resolution images where limited storage onboard satellite and limited transmission bandwidth are available. The CCSDS Recommended Standard for Image Data Compression is planned to be suitable for spacecraft utilization and its complexity is sufficiently low for hardware implementation and memory buffer requirement is also low. It can support strip-based input format as well as frame based input format. This compressor DWT (discrete wavelet transform) and second Bit Plane Encoding (BPE). The BPE performs DC (Low frequency component) and AC(high frequency component) data encoding by obtaining DWT coefficients. In this paper section II contains brief description of CCSDS standard algorithm, from which DC compression performs lossy compression. Section III contains parameters of compression. Section IV contains result analysis, which determines the lossy compression on different images with their compression parameters and also compares CCSDS standard with JPEG2000 standard at high compression ratio.

II. CCSDS STANDARD RECOMMENDATION [1][2]

The CCSDS Standard Recommendation for Image Data Compression specified for gray scale pictures with maximume bit-depth is 16 and its its specification is, it required less hardware resource. The basic block diagram of CCSDS Standard Recommendation contains DWT and BPE.

![Fig. 1: Basic Block Diagram of CCSDS Standard Recommendation][1]

DWT gives 3-level of image transformation for two dimensional images and BPE gives further encoding of the DWT output. BPE is coded in three section: (1) DC Coding (2) AC-BitDepth coding (3) AC Bit Plane Coding.

A. Basic Compression Process:

This Recommended Standard for the de-correlation module makes use of a three-level, two-dimensional Discrete Wavelet Transform (DWT) with nine and seven taps for low- and high-pass filters, respectively.

Two specific 1-d wavelets are specified with this Recommended Standard: the 9/7 bi-orthogonal DWT, referred to as '9/7 Float DWT” or simply 'Float DWT”, and a non-linear, integer approximation to this transform, referred to as ‘9/7 Integer DWT” or simply ‘Integer DWT”. While the Float DWT generally exhibits superior compression efficiency in the lossy domain, only the Integer DWT supports strictly lossless compression. Image data is assumed to use R-bit pixels to represent either signed or unsigned integerValues, where R≤16.

After DWT processing, initial DC coding (Low frequency coefficients) is done, for the Bit Plane Encoder handles DWT coefficient for data compression. For compression process use DWT coefficents which is scaled by using different quantization value. The Bit Plane Encoder...
encodes a segment of images from most significant bit (MSB) to least significant bit (LSB). BPE retrieves the wavelet domain data and uses different compression scheme for different DWT sub-band data. According to various compression ratio requirements, BPE performs data truncation if constant rate data is required. After necessary header information is added, the compressed data is sent to mass memory word by word for storage. The BPE performs DC (Low frequency coefficients-LL3 band of DWT) and AC (High frequency coefficients)data compression , In AC part maximum value of each block will be computed, further to achieving more quality of image AC bit plane coding is done plane by plane, in AC part data, it consists of 5 stages . BPE:

After DWT processing, the Bit Plane Encoder handles DWT coefficient for data compression. The Bit Plane Encoder encodes a segment of images from most significant bit (MSB) to least significant bit (LSB). BPE retrieves the wavelet domain data and uses different compression scheme for different DWT sub-band data. According to various compression ratio requirements, BPE performs data truncation if constant rate data is required. After necessary header information is added, the compressed data is sent to mass memory word by word for storage. The BPE performs DC and AC data compression as the flow shown in Fig. 4. In AC part maximum value of each block will be computed, further to achieving more quality of image AC bit plane coding is done plane by plane, in AC part data, it consists of 5 stages.\[4\]

The Bit Plane Encoder (BPE) processes wavelet coefficients in groups of 64 coefficients referred to as block from which a single DC coefficient (LL3 sub-bend) and its corresponding 63 AC coefficients (Fig.2).

The AC coefficients in a block are arranged into three families, F0, F1 and F2. Each family Fi in the block has one parent coefficient, pi, a set Ci of four children coefficients, and a set Gi of sixteen grandchildren coefficients. The grandchildren in family Fi are further partitioned into groups numbered j=0,1,2,3,i=0,1,2 denoted Hij, as illustrated in Fig.3. This structure is used for jointly encoding information pertaining to groups of coefficients in the block.\[112\]

Sixteen consecutive blocks constitute a gaggle and sequence of gaggle form a segment.

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### II. DC Encoding:

This is a part of the BPE coding and is done for LL3 coefficients of DWT, which is a low frequency component. This is done in three parts; first part takes the quantization value which is obtained by truncating value of LL3 coefficients using quantized factor which determine from DC_MAX_Depth and AC_MAX_Depth.

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**Flow Chart of the DC Coding Act As Lossy Compression**

DC_MAX_Depth and AC_MAX_Depth are determined by finding bits of maximum value from DC coefficients and finding bits of maximum value AC coefficients respectively. Second part finds Deference of quantization value (δm') and the third part is non-negative mapping (δm) (Fig.3). The Golomb Rice coding technique is used for DC encoding on δm. After getting values of δm, Golomb-Rice coding is applied on δm. And codedata was sent in particular Fram. In this Fram, first comes code option which is desided on value of N ,then coded data are send. This coding option selection process and Rice coding are done within a gaggle.

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### B. Quantization Factor:

This value desided that how many bits is quntized from BitDepthDC. Basically this value truncates the number of bits from the pixel depth and only using remaining bits further coding is done. So, number of quantization bits values are increase then reduced the value of coded bits, so less number of bits are needed for further coding process. By increasing the value of Quantization Factor which directaly increase the Compression ratio.

But there is trade off between compression ratio and image visualization effect. When Compression ratio is increase then image visualization is decrease , so we can not go beyode the value of CR at which image visualization is disappeare. So, we stop to decrease the value of quantization factor and desided value up to which image recostrution is possible with its appearance of visualization.

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### III. STANDARD PARAMETERS

#### A. Mean Square Error (MSE):

It gives error between original and compressed images.

\[
MSE = \sum_{k=0}^{n} \sum_{k=0}^{n} (x'i,j - xi,j)^2
\]

Where: \(x'i,j\) = original image pixel value

\(xi,j\) = compressed image pixel value

\(i, j\) = raw and column f image

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B. **PSNR:**

Peak Signal to Noise ratio gives the quality of image if PSNR is high, then quality of compressed image is good.

\[
\text{PSNR} = 20 \log_{10} \frac{2B}{\sqrt{MSE}}
\]  

Where: \( B \) = Bit Depth of the original image

C. **Compression Ratio (CR):**

The ratio of uncompressed file to compressed file called the compression ratio. It gives information that how much time image is compressed to original.

\[
\text{Compression Ratio} = \frac{\text{Uncompressed ImageBits}}{\text{Compressed ImageBits}}
\]  

D. **Maximum Absolute Error (MAE):**

It gives maximum error of compressed image compared with the original image

\[
\text{MAE} = \max | X_{i,j} - X'_{i,j} |
\]  

Where: \( X_{i,j} \) = original image pixel value  
\( X'_{i,j} \) = compressed image pixel value  
\( i,j \) = raw and column of image

ratio. The presented algorithm can be implemented on FPGA hardware with less utilization of resources.

IV. **RESULT ANALYSIS**

Different quantization factor applied on various images. According to value of quantized factor shows the effect on reconstructed image from the below analysis. When quantized factor is increase Compression ratio will increase but PSNR will decrease. So various effects are in image that can justified by image parameters.

Here take various size of image like cameraman (256 X 256 Resolution), Trui (256 X 256 resolution), Leena (512 X 512 resolution) and Trees (resolution). On each images applied different quantization values and from which obtained the value of quantization factor from which stop to reduce quantization factor value. Because here we try to identify that at which value we can quantized and got better compression ratio.

A. **Graphical representation of Compression parameter**

When reducing quantization factor that reflect the image reconstruction. Quantization factors values are

1) **MAE vs. PSNR:**

![Graphical representation of Compression parameter](image)

B. **PSNR vs. CR:**

![Graphical representation of Compression parameter](image)
1) PSNR vs. Bpp

![Graph of PSNR vs. Bpp](image1)

Fig. 7: Different Images - Psnr-Bpp : (A) Cameramen (B)Trees (C)Leena (D) Trui

C. Visualization representation of Compression parameter on different quantization factor:

When quantization factor is increase image visualization will decrease

![Graph of Different Images Visualization](image2)

Fig. 8: Different Images Visualization : (A) Cameramen (B)Trees (C)Leena (D) Trui

**D. Tabl For Compering Compression Parameter On Different Quantization Factor:**

<table>
<thead>
<tr>
<th>Quantization Factor</th>
<th>PSNR</th>
<th>CR</th>
<th>MAE</th>
<th>BPE</th>
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</table>

**Table 1:** Different Parameter for Different Quantization Factor

From above fig 5 to fig 8 and from table 1 show that upto quantize factor 7 to 8 and its dynamic range upto 12-19 we can reconstructing the image with image visualization availability after that visualization is not available in reconstructed image.

V. CONCLUSION AND FUTURE SCOPE

In high compression ratio applications to reduce bandwidth, transmission rate, transmission time like interplanetary mission. This Lossy compression standard obtained by implementing only up to DC-algorithm; eliminating coding of further stages gives high compression ratio. Also show that up to DC-coding lossy compression can also increase by increasing quantize factor. And up to 7 to 8 values of quantize value, we can reconstructing the image.
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