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Bit Depth Optimization In DCT-IV for Extended JPEG

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Abstract*: A discrete cosine transform (DCT) expresses a finite sequence of data points in terms of a sum of cosine functions oscillating at different frequencies. DCTs are vital to varied applications in science and engineering, from lossy compression of audio (e.g. MP3) and images (e.g. JPEG) (where small high-frequency components can be discarded to spectral ways for the numerical answer of partial differential equations. The modified discrete cosine transform (MDCT) is a lapped transform based on the type-IV discrete cosine transform (DCT-IV), with the additional property of being lapped: it is designed to be performed on consecutive blocks of a larger dataset, wherever later blocks are unit overlapped so that the last half of one block coincides with the first half of the next block. Energy crisis in multimedia devices has resulted in poor quality of image/video resolution. These devices use compression standard, having Discrete Cosine Transform (DCT) as core computation intensive component. This work presents a novel approach to have an effective computation based on behavior of pixels, pixel approximation, and multiplicand value decision. We propose an energy aware computation driven approximate DCT architecture/compression. Reducing the simulation time by sacrificing the quality of an image with a new concept of error resilient. Further we introspect the computational time of matrix multiplications and coefficients scaling based on pixel behaviors. At last compare the results with new parameters like FSIM, SSIM etc.

Keywords*:* JPEG,DCT,MDCT,PSNR,FSIM,SSIM,GMSD;

1. Introduction

In present era, Multimedia has become an integrated part of every communication and the source of information contains raw data like message, image's, video's, etc. These constitute the flow of large amount of data into network. Images are generated, edited and transmitted on a very regular basis in a vast number of systems today. The raw image data generated is very voluminous to store and hence not very economical. It becomes particularly cumbersome to move it around in bandwidth constrained systems or where bandwidth is to be conserved for cost purposes such as the World Wide Web. Many of multimedia applications mainly deal with image and video data, because human are more susceptible towards images, or picture perception. Even with small quality degradation may not effect human perception with correct resolution of image. Image data which is processed for communication mainly undergo with some standards of Digital Image Processing (DIP) compression like JPEG (Joint Photographic Expert Group), MPEG-x (Motion Picture Expert Group), which begins major component in today's data centered world. Such scenarios demand use of efficient image compressing techniques such as the JPEG algorithm technique which compresses the image to a high degree with little loss in perceived quality of the image.

Joint Photographic Expert Group(JPEG)[5]

Lossy JPEG is an example of a transform coding technique A classic diagrammatic depiction of this approach to lossy compression is given in Figure 1. In fig. (a) The forward transform, is applied to an input signal yielding an alternate form of it that can be manipulated for compression toward greater compressibility by means of the next stage: quantization more severely we quantize, the more compression we can achieve. This is called as quality versus compression trade-off. At final Stage data compression is applied to the quantized data. A process conventionally referred to as entropy coding. Typically Huffman coding or Arithmetic coding is employed in Image Compressions. Fig. (b) also shows the decoding stage. Here we have a tendency to undo the actions performed by the encoder, only in the reverse order.

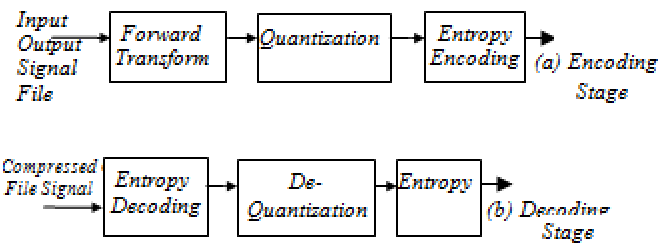

Figure 1: Lossy Compression Using Transform Encoding

Discrete Cosine Transform[4]

While Studying the Structures/Standards of Image/Video, the most prominent and computing part is Discrete Cosine Transform (DCT). DCT transforms the signal or data in the form of low to high frequency speeded in various locations for proposed block of data. The hierarchical mode can use DCT based coding or predictive coding. Most widely used mode in practice is called the baseline JPEG system, that is predicated on successive mode, DCT-based coding and Huffman coding for entropy encoding. Fig. 2 block diagram of baseline system.

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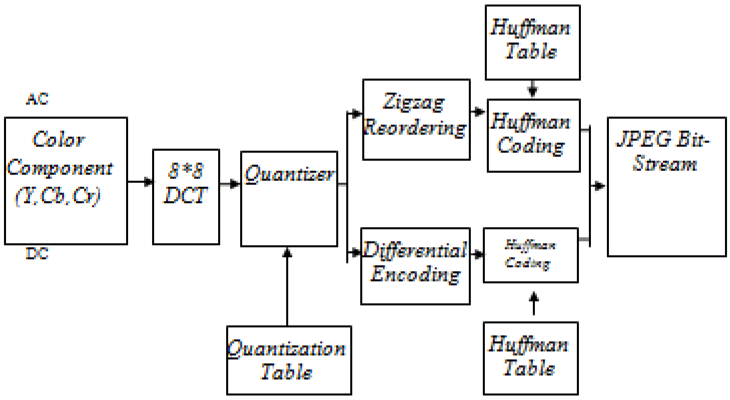

Figure 2: Block diagram of baseline system

Because of its lossy compression which hardly to detect with human eye, this has open a new area of research for multimedia operation with constraints as imprecise computation or approximate computation. Approximation can be used in the application where human sense is required, because human eye is unable to recognize correct image or approximate image with accuracy greater than 95%. By using approximation we can improve the computation time means delay, area required to implement that circuit, hardware cost etc.

In case of JPEG, the forward transform used in the 2D discrete cosine transform. For 8*8 sub-block of image the 2-D DCT is given by

$$F(k,l) = \frac{C(k)}{2}\frac{C(l)}{2}\sum_{i=1}^{8}.\sum_{j=1}^{8}.\mathrm{A(i,j)}cos\left[\frac{(2i-1)(k-1)\pi}{16}\right]cos\left[\frac{(2j-1)(k-1)\pi}{16}\right]$$

for k = 1,2,…,8 , l=1,2,…,8

$$\text{where } C(n)=\begin{cases}\frac{1}{\sqrt{2}}, n=1 \\ 1 \text{ otherwise.}\end{cases}$$

Each block A of 64 numbers in the spatial domain is associated with a unique block F, consisting of 64 numbers in the frequency domain. Therefore the numbers F(k; l) are called frequency components of A.The first coefficient F(1; 1) is called the DC coefficient, since it corresponds to the basis function of frequency 0, while the others are called AC coefficients.

The inverse transform is defined as

$$A(i,j) = \sum_{k=1}^{8}.\frac{C(k)}{2}\sum_{l=1}^{8}.\frac{C(l)}{2}\mathrm{F(k,l)}cos\left[\frac{(2i-1)(k-1)\pi}{16}\right]cos\left[\frac{(2i-1)(k-1)\pi}{16}\right]$$

for i = 1,2,…,8 ,j=1,2,…,8

Modified Discrete Cosine Transform(MDCT)

To deal with the problem of discontinuities we investigate the use of the windowed MDCT as an alternative to the DCT. The modified discrete cosine transform (MDCT) is a lapped transform based on the type-IV discrete cosine transform (DCT-IV), with the additional property of being lapped. It is designed to be performed on consecutive blocks of a larger dataset, where subsequent blocks are overlapped so that the last half of one block coincides with the first half of the next block. Standard DCT would map N samples of data to N new values, the MDCT maps an N-sample block, say x, to a block consisting of N/ 2 new values, say X.

For input block x=[x1, x2, x3….x_n] its MDCT X is defined as

$$\mathrm{X(j)} = \sum_{i=1}^{N}.x(i)\,cos\left(\frac{2\pi}{N}\left(i+\frac{N}{4}-\frac{1}{2}\right)\left(j-\frac{1}{2}\right)\right)$$

for j=1,2,……N/2.

The inverse" transform (IMDCT) is defined as.

$$\hat{x}(\mathrm{i}) = \frac{2}{N}\sum_{j=1}^{N/2}.X(j)\,cos\left(\frac{2\pi}{N}\left(i+\frac{N}{4}-\frac{1}{2}\right)\left(j-\frac{1}{2}\right)\right)$$

for i=1,2,……N.

2. Literature Review

The initial focus of research efforts in this field was on the development of analog methods for reducing video transmission bandwidth, a process called bandwidth compression. The advent of the digital computer and subsequent development of advanced integrated circuits, however, caused interest to shift from analog to digital compression approaches. As the technology changing the use of compression is more and demanding still the efficient process of reducing the size. DCT is the core computational block in image compression , where DCT is used to transform the data into frequency domain many researchers have provided different approach to reduce simulation time or memory efficiency or both at both software and hardware level.

Kankan et al: [3] proposed a multilevel DCT based Zero tree coding for JPEG 2000. The main ideology in this paper is replacing DWT with DCT and their coefficients are subsample in bands according to their frequency level group. But in an image there are three levels of color data with different spatial resolutions, where Multi level DCT performance is effective only on low band data frequencies because the higher level DCT is performed on only low sub bands.

Dong, Xiuyuan, et al [2]mainly focused on hardware accelerator of JPEG targeting in reducing the hardware complexity and increasing the throughput. In this DCT is calculated on First order moments which is of high structural regularity. Reznik, Yuriy A [6] provided a case study between DCT types and DST and their application in compression units. The DCT-II is used at the core of standards for image and video compression, such as JPEG, ITU-T H.26x-series, and MPEG 1-4 standards. The DCT-IV is used in audio/video coding algorithms, such as ITU-T Rec. G.722.1, MPEG-4 AAC, JPEG EX, and others. Such transforms are very well

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studied, and a number of efficient techniques exist for their computation. Pennebaker et al focus on one of the main obstacles in performing accurate DCT computations is the implementation of the irrational coefficient multiplications needed to calculate the transform. Traditional DCT implementations adopt a compromise solution to this problem, employing truncation or rounding off to approximate these quantities. As a consequence, computational errors are systematically introduced into the computation, leading to the degradation of the signal-to-noise ratio (SNR).To partially address this issue, algebraic integer (AI) encoding has been employed. The main idea in this approach is to map required irrational numbers into an array of integers, which can be arithmetically manipulated in an error free manner. At the end of the computation, AI based algorithms require a final reconstruction step (FRS) in order to map the resulting encoded integer arrays back into the usual fixed-point representation. FRS can be implemented by means of individualized circuits, at, in principle, any given precision. Cintra et al [8] mainly focus on reducing the complexity of DCT computations. An orthogonal approximation is followed in this method where zeros and ones are presented in place of multiplication and add shift bits.

From all the above we see the research is focused either on the complexity of DCT or coefficients modulation of DCT. But the simulation time taken by DCT is still not efficient one and suffering from critical sampling. The matrix data (pixel data) can be approximated on less human vision focus areas in an image which lead to reduce the simulation time. So image can be still validate. Work is completely at the algorithm level where focusing on the reducing the complexity and reducing the number of operations.

At the algorithm level where focusing on the reducing the complexity and reducing the number of operations. DCT at hardware level has been also employed. Low Power DCT structure are very popular nowadays, & can be realize with MAC (Multiply Accumulate) unit and computation sharing multiplication CSHM[10] which reduces the computation susceptible to small or no quality degradation. This seems to have an energy aware design in nano-meter regime and raise the structure as Process- variation aware because parametric variation below 90nm raise the question of redesigning of the structure of DCT, with more/less significantly contributing coefficients, with data path redesigning. The design discussed reduces the pre-computers & Select/Shift and Add units and obtain the skew in different path-length. This guarantees the DCT architecture to be one of the fruitful under the process variation effect and can provide the best result in every circumstance. Voltage Over Scaling is required for error resiliency subjected to process variation analysis. This raises the problem of over computation as VOS[11], for delay of some less significant part. Dynamic reconfigurable DCT provides the examination of input bit stream and then reconfigure the DCT to have optimal computation in result will have area over head which becomes the problem of this approach. The arithmetic involve is distributed arithmetic[16] which becomes very popular nowadays requires ROM based coefficient storage, while cordic based DCT are also available which produces coefficient accordingly. In context to approximation component development taking into account as various type of adder (as adder is prime component of DIP), like ETA (Error Tolerance Adder), Variable Latency Speed Adder.

The 1D-DCT transforms Image in one dimension. This can be extends to 2D-DCT in similar fashion and the analysis is carried out provides that, component are arranged in increasing order of frequency. To archive for error resiliency/tolerant, Speed, Power, Area and Accuracy will be a challenging part to achieve, many a time trade-off scenario is observed.

Parameters to Evaluate the Image

1) PSNR(Peak Signal to Noise Ratio)[17]
2) SSIM (Structural Similarity Based Image Quality Assessment)[14]
3) FSIM (Feature Similarity Index For Image Quality Assessment)[13]
4) GMSD(Gradient Magnitude Similarity Deviation)[11]
5) RFSIM (Riesz-transform based Feature Similarity metric)[12]

3. Research Gap

Error Resilient feature of Image Compression is not fully utilized in terms of

- Optimized hardware
- Power requirement
- Coefficient aware design
- Optimization in JPEG architecture

4. Conclusion

Present era has witnessed tremendous improvement in multimedia applications with growing data traffic in network, which results in improper energy utilization on portable devices. These data are compressed without compromise of quality and certainly up to 10% degradation in quality is tolerable/acceptable as per human perception. This well-known feature is utilized in Digital Image Processing (DIP) applications like JPEG, MPEGx, etc. The study of image/video encoder provides detail of prominent compressor unit i.e., Discrete Cosine Transform (DCT) block; which transforms the signal or data from spatial domain to frequency domain and arranges it from low to high frequency. As an outcome of literature review, we came to know based on pixel behavior that fewer coefficients are required to process from input end in comparison to conventional multiplier based DCT.

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