DCT Color Image Compression using VHDL

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Abstract:-Digital images require large amounts of memory to be stored in a computer system. The JPEG compression standard allows the amount of memory storage required by a digital image to be reduced with little to no perceptible loss of image quality. This thesis is a design of an ASIC that implements a decoder of JPEG compressed images. The decoder implements the baseline decoder defined by the JPEG standard with a few exceptions, the most notable being that only grayscale images can be decompressed. With such an ASIC, the speed of decompressing images is greatly increased. The decoder was designed by writing VHDL source code, which in turn was used to synthesize the ASIC using standard cells. This paper describes a VHSIC Hardware Description Language (VHDL) simulation of a hardware 8x8 Discrete Cosine Transform (DCT) which can be applied to image compression. A Top-Down Design approach is taken in the study, a discussion of DCT theory is presented, along with a description of the 1-D DCT circuit architecture and its simulation in VHDL. Results of the 2-D DCT simulation are included for two simple test patterns and verified by hand calculation, demonstrating the validity of the simulation. Shortcoming found in the simulation are described, together with suggestions for correcting them. In the future, the VHDL description of the 8 x 8 image block 2-D DCT can be further developed into structural and gate-level description, after which hardware circuit implement can occur..

IndexTerms—DCT,Modelsim,SNR,ASCII,Zigzag.

I. INTRODUCTION

By entering the Digital Age, the world has faced a vast amount of information. Dealing with this vast amount of information can often result in many difficulties. We must store, retrieve, analyze and process Digital information in an efficient way, so as to be put to practical use. In the past decade many aspects of digital technology have been developed. Specifically in the fields of image acquisition, data storage and bitmap printing. Compressing an image is significantly different than compressing raw binary data. Images have certain statistical properties which can be exploited by encoders specifically designed for them so, the result is less than optimal when using general purpose compression programs to compress images. One of many techniques under image processing is image compression. Image compression have many applications and plays an important role in efficient transmission and storage of images. The image compression aims at reducing redundancy in image data to store or transmit only a minimal number of samples And from this we can reconstruct a good accession of the original image in accordance with human visual perception.

1.1Principles Behind Compression Image Compression addresses the problem of reducing the amount of data required to represent the digital image. We can achieve compression by removing of one or more of three basic data redundancies:

(1) Spatial Redundancy or correlation between neighboring pixel.

(2) Due to the correlation between different colour planes or spectral bands, the Spectral redundancy is founded.

(3) Due to properties of the human visual system ,the Psycho-visual redundancy is founded.

We find The spatial and spectral redundancies when certain spatial and spectral patterns between the pixels and the colour components are common to each other and the psycho-visual redundancy produces from the fact that the human eye is insensitive to certain spatial frequencies. Various techniques can be used to compress the images to reduce their storage sizes as well as using a smaller space. We can use two ways to categorize compression techniques. Lossy Compression System Lossy compression techniques is used in images where we can sacrifice some of the finer details in the image to save a little more bandwidth or storage space. - Lossless compression system Lossless Compression System aims at reducing the bit rate of the compressed output without any distortion of the image. The bit-stream after decompression is identical to the original bitstream. - Predictive coding It is a lossless coding method, which means the value for every element in the decoded image and the original image is identical to Differential Pulse Code Modulation (DPCM). - Transform coding Transform coding forms an integral part of compression techniques. the reversible linear transform in transform coding aims at mapping the image into a set of coefficients and the resulting coefficients are then quantized and coded. the first attempts is the discrete cosine transform (DCT) domain.

1.2 Atypical Image Coder Three closely connected components form a typical lossy image compression system, they are (a) Source Encoder (b) Quantizer and (c) Entropy Encoder.

(a) Source Encoder (or Linear Transformer) It is aimed at decorrelating the input signal by transforming its representation in which the set of data values is sparse, thereby compacting the information content of the signal into smaller number of coefficients. a variety of linear transforms have been developed such as Discrete Cosine Transform (DCT), Discrete wavelet Transform (DWT), Discrete Fourier Transform (DFT).

(b) Quantizer A quantizer aims at reducing the number of bits needed to store transformed coefficients by reducing the precision of those values. Quantization performs on each individual coefficient i.e. Scalar Quantization (SQ) or it performs on a group of coefficients together i.e. Vector Quantization (VQ).

(c) Entropy Coding Entropy encoding removes redundancy by removing repeated bit patterns in the output of the Quantizer. the most common entropy coders are the Huffman Coding, Arithmetic Coding, Run Length Encoding (RLE) and Lempel-Ziv (LZ) algorithm.

II INTRODUCTION

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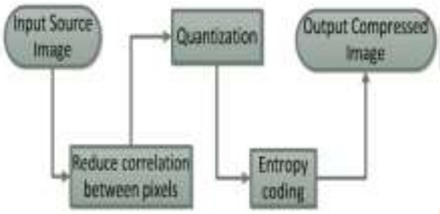

Figure 1.represents the encoding of image compression system

II LITERATURE REVIEW

In Lossless techniques the image can be reconstructed after compression, without any loss of data in the entire process. The image compression and decompression is identical to original image and every bit of information is preserved under decomposition process. Reconstructed image is replica of original image. Although there is deterioration in image quality. Lossless image compression is basically used in those where no loss of data can be compromised. It can be used for document and medical imaging. Lossy techniques, on the other hand are irreversible, because, they involve performing Quantization, which result in loss of data. Lossy compression can be used for signals like natural images, speech [2]etc, where the amount of loss in the data determines the quality of the reconstruction and does not lead to change in the information content. Reconstructed image contains degradation with respect to its original image. There are small amount of redundancies present. It can be used for multimedia applications. More compression is achieved in the case of lossy compression than lossless compression. Compression of images involves taking advantage of the redundancy in data present within an image. Vector quantization is often used when high compression ratio are required. Any compression algorithm is acceptable provided a corresponding decompression algorithm exits. Vector Quantization(VQ) achieves more compression then scalar quantization, making it useful for band-limited channels. Numerous compression techniques have been developed such as vector quantization, block truncation method , transform coding ,hybrid coding and various adaptive versions of this methods. Among these techniques, vector Quantization is widely used in image compression owing to its simple structure and low bit rate. In the process of vector Quantization the image to be encoded is segmented into a set of input image vectors. The most important task for the VQ scheme is to design a good codebook. A good codebook is required because the reconstructed image highly depends on the codewords in this very codebook. The generated codebook store into text file for vhdl file handling or data array in vhdl code. The algorithm for the design of optimal VQ is commonly referred to as the Linde-Buzo-Gray(LBG) algorithm, and it is based on minimization of the squared-error distortion measure. In 1980, Linde, Buzo, and Gray proposed the VQ scheme for grayscale image compression and it has proven to be a powerful tool for both speech and digital image compression. There are three major procedures in VQ, namely codebook generation, encoding procedure and decoding procedure. In the codebook generation process, various images are divided into several k-dimension training vectors. The representative codebook is generated from these training vectors by the clustering techniques. In the encoding procedure, an original image is divided into several k-dimension vectors and each vector is encoded by the index of codeword by a table look-up method. The encoded results are called an index table

II METHODOLOGY

Image compression is used for managing images in digital format. This survey paper has been focused on the Fast and efficient lossy coding algorithms JPEG for image Compression/Decompression using Discrete Cosine transform. We also briefly introduced the principles behind the Digital Image compression and various image compression methodologies .and the jpeg process steps including DCT, quantization , entropy encoding.

This program implements color images, whereas the design in VHDL only does grayscale images. Ideally the behavioral model would be done in VHDL, to help in the design of the structural model. Figure 2 shows an overview of how the VHDL design model simulates decoding JPEG compressed images.

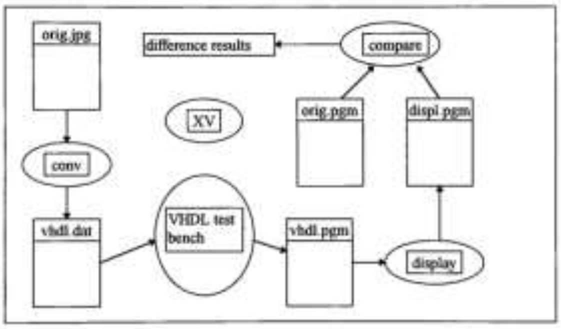

Figure 2. Overview of design test flow

2 . DISCRETE COSINE TRANSFORM(DCT):

A. Color Space Converter :The process of the JPEG starts with color space conversion. This process is not applicable to gray-scale image, where there is only one luminance component for gray scale image. Color image data in computers is usually represented in RGB (Red-Green-Blue) format. Each color component uses 8 bits to store, thus, a full color pixel would require 24 bits. From the fact that human eyes are more sensitive to intensity change rather than color change, the JPEG algorithm exploits this by converting the RGB format to another color space called YCbCr. Y is luminance component, Cb and Cr are chrominance components. After converting the color space, the encoder stores the luminance Y in more detail than the other two chrominance components.The Y component represents the brightness of a pixel, the Cb and Cr components represent the chrominance (split into blue and red components). This is the same color space as used by digital color television as well as digital video including video DVDs, and is similar to the way color is represented in analog PAL video and MAC but not by analog NTSC, which uses the YIQ color space. The YCbCr color space conversion allows greater compression without a significant effect on perceptual image quality (or greater perceptual image quality for the same compression). The compression is more efficient as the brightness information, which is more important to the eventual perceptual quality of the image, is confined to a single channel, more closely representing the human visual system. The RGB image is converted to YCbCr by using the following equations

$$Y = 0.299R + 0.587G + 0.114B$$

$$Cb = 0.564B - 0.564\,Y$$

$$Cr = 0.713R - 0.713\,Y$$

B. Down Sampling :Due to the densities of color- and brightness sensitive receptors in the human eye, humans can see considerably more fine detail in the brightness of an image (the Y component) than in the color of an image(the Cb and Cr components). Using this knowledge, encoders can be designed to compress images more efficiently. The transformation into the YCbCr color model enables the next step, which is to reduce the spatial resolution of the Cb and Cr components (called "down sampling" or "chroma sub sampling"). The ratios at which the down sampling can be done on JPEG are 4:4:4 (no down sampling), 4:2:2 (reduce by factor of 2 in horizontal direction), and most commonly 4:2:0(reduce by factor of 2 in horizontal and vertical directions). For the rest of the compression process, Y, Cb and Cr are processed separately and in a very similar manner. Down sampling the chroma components saves 33% or 50% of the space taken by the image without drastically affecting perceptual image quality.

C. Block Splitting :After sub sampling, each channel must be split into 8×8 blocks (of pixels). If the data for a channel does not represent an integer number of blocks then the encoder must fill the remaining area of the incomplete blocks with some form of dummy data: Filling the edge pixels with a fixed color (typically black) creates dark artifacts along the visible part of the border. Repeating the edge pixels is a common but non optimal technique that avoids the visible border, but it still creates artifacts with the colorimetric of the filled cells. A better strategy is to fill pixels using colors that preserve the DCT coefficients of the visible pixels, at least for the low frequency ones (for example filling with the average color of the visible part will preserve the first DC coefficient, but best fitting the next two AC coefficients will produce much better results with less visible 8×8 cell edges along the border).

D. Discrete Cosine Transform (DCT) :The discrete cosine transforms (DCT) is a technique for converting a signal into elementary frequency components. It is widely used in image compression. Before compression, image data in memory is divided into several blocks MCU (minimum code units). Each block consists of 8x8 pixels. Compression operations including DCT-2D in it will be done on each block [2]. Two dimensional DCT, because of its advantage in image compression, is an interesting research subject that makes many algorithms of DCT is developed.

E. 2-D Discrete Cosine Transform (DCT) There are several ways to compute 2-D DCT. It can be computed with straightforward computation just multiply input vector by raw DCT coefficients without any algorithm [3]. This method is fast but need large logic utilization, especially multiplier. This method is fully pipelined in this paper. FPGA chip usually has only a few multipliers. In this case, Spartan-3E XCS500E has only 11 multipliers. This paper adopts the work of [3] The Discrete Cosine Transform is an orthogonal transform consisting of a set of basis vectors that are sampled cosine functions. The 2-D DCT of a data matrix is defined as equation (1)

$$Z = C\,X\,C^T$$

Where X is the data matrix, C is the matrix of DCT Coefficients, and Ct is the Transpose of C.

$$Z=\begin{bmatrix} c_{00} & c_{01} & \cdots & c_{07} \\ c_{10} & c_{11} & \cdots & c_{17} \\ \vdots & \vdots & \vdots & \vdots \\ c_{70} & c_{71} & \cdots & c_{77} \end{bmatrix} \begin{bmatrix} x_{00} & x_{01} & \cdots & x_{07} \\ x_{10} & x_{11} & \cdots & x_{17} \\ \vdots & \vdots & \vdots & \vdots \\ x_{70} & x_{71} & \cdots & x_{77} \end{bmatrix} \begin{bmatrix} c_{00} & c_{10} & \cdots & c_{70} \\ c_{01} & c_{11} & \cdots & c_{71} \\ \vdots & \vdots & \vdots & \vdots \\ c_{07} & c_{17} & \cdots & c_{77} \end{bmatrix}$$

Where, for an N x N data matrix. The complete multiplication algorithm is presented in Table. 1, where: in1 = cos(4d16) m3 = cos(2d16) - cos(6d16) m2 = cos(6d16) m4 = cos(2dI6)+ cos(6dl6))

Step 1		
b0 = a0 + a7	b1 = a1 + a6	b2 = a2 - a4
b3 = a1 - a6	b4 = a2 + a5	b5 = a3 + a4
b6 = a2 - a5	b7 = a0 - a7	
Step 2		
c0 = b0 + b5	c1 = b1 - b4	c2 = b2 + b6
c3 = b1 + b4	c4 = b0 - b5	c5 = b3 + b7
c6 = b3 + b6	c7 = b7	
Step 3		
d0 = c0 + c3	d1 = c0 - c3	d2 = c2
d3 = c1 + c4	d4 = c2 - c5	d5 = c4
d6 = c5	d7 = c6	d8 = c7
Step 4		
e0 = d0	e1 = d1	e2 = m3 x d2
e3 = m1 x d7	e4 = m4 x d6	e5 = d5
e6 = m1 x d3	e7 = m2 x d4	e8 = d8
Step 5		
f0 = e0	f1 = e1	f2 = e5 + e6
f3 = e5 - e6	f4 = e3 + e8	f5 = e8 - e3
f6 = e2 + e7	f7 = e4 + e7	
Step 6		
S0 = f0	S1 = f4 + f7	S2 = f2
S3 = f5 - f6	S4 = f1	S5 = f5 + f6
S6 = f3	S7 = f4 - f7	

Table 1 1-D DCT Agostini algorithm

The 2-D DCT (8 x 8 DCT) is implemented by the row-column decomposition technique. We first compute the 1-D DCT (8 x 1 DCT) of each column of the input data matrix X to yield Xt C .after appropriate rounding or truncation, the transpose of the resulting matrix, Ct X, is stored in an transpose buffer. We then compute another 1- D DCT (8 x 1 DCT) of each row of Ct X to yield the desired 2-D DCT as defined in equation (1). A block diagram of the design is shown in Fig 2.

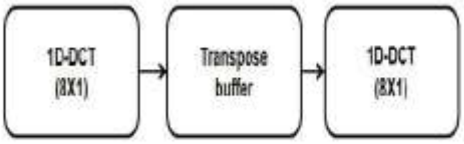

Figure 2: 2D-DCT Architecture

F. Quantization Our 8x8 block of DCT coefficients is now ready for compression by quantization. A remarkable and highly useful feature of the JPEG process is that in this step, varying levels of image compression and quality are obtainable through selection of specific quantization matrices. This enables the user to decide on quality levels ranging from 1 to 100, where 1 gives the poorest image quality and highest compression, while 100 gives the best quality and lowest compression. As a result, the quality/compression ratio can be tailored to suit different needs. Subjective experiments involving the human visual system have resulted in the JPEG standard quantization matrix. With a quality level of 50, this matrix renders both high compression and excellent decompressed image quality. From [1] the Quantization matrix is obtained.

$$Q_{50}=\begin{bmatrix} 16 & 11 & 10 & 16 & 24 & 40 & 51 & 61 \\ 12 & 12 & 14 & 19 & 26 & 58 & 60 & 55 \\ 14 & 13 & 16 & 24 & 40 & 57 & 69 & 56 \\ 14 & 17 & 22 & 29 & 51 & 87 & 80 & 62 \\ 18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\ 24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\ 49 & 64 & 78 & 87 & 103 & 121 & 120 & 101 \\ 72 & 92 & 95 & 98 & 112 & 100 & 103 & 99 \end{bmatrix}$$

Figure 3. Quantization Matrix

G. Zigzag Reordering Buffer Each block of data that is output by the quantization module needs to be reordered in a zigzag. This reordering is achieved using an 8 x 8 array of register pairs organized in a fashion similar to the transpose buffer. Quantized output is sent sequentially byte-by-byte in zigzag pattern. Zigzag operation is done for every 8X8 block. The pattern is shown in figure 2 [1]. Numbers listed in the figure are the address of 64 data that is arranged in a zigzag pattern.

0	1	8	16	9	2	3	10
17	24	32	25	18	11	4	5
12	19	26	33	40	48	41	34
27	20	13	6	7	14	21	28
35	42	49	56	57	50	43	36
29	22	15	23	30	37	44	51
58	59	52	45	38	31	39	46
53	60	61	54	47	55	62	63

Figure.4 Zigzag Pattern

Applications :

The image compression has diverse application including:

1) Document and medical imaging

2) Remote sensing

3) Tele-video conferencing

II CONCLUSION

Image compression is used for managing images in digital format. This survey paper has been focused on the Fast and efficient lossy coding algorithms JPEG for image Compression/Decompression using Discrete Cosine transform. We also briefly introduced the principles behind the Digital Image compression and various image compression methodologies .and the jpeg process steps including DCT, quantization , entropy encoding.

Data transfer of uncompressed image over digital networks require very high bandwidth. The state of the art image compression techniques may exploit the dependencies between the subbands is a transferred image. The above proposed algorithm reduces the complexity of a transferred image without sacrificing performance. Vector quantization is an established lossy compression technique that has been used successfully to compress signals such as speech, music, video, imagery.

LBG is an easy and Rapid algorithm. However, it has the local optimal problem which is that for a given initial solution, it always converges to the nearest local minimum. In other words, LBG is a local optimization procedure. The other problem with LBG algorithm is the codeword generation process needs a great deal of calculation. Thus, LBG is relatively slow algorithm. Consider the shown example of a squirrel. The original image has undergone compression and it ratio, along with mean square error (MSE) and peak signal tonoise ratio are elaborately compared.

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