VIDEO HARDWARE SYSTEM AND IMAGE COMPRESSION USING THE DCT

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ABSTRACT.

In this paper we show the obtained results when using the Discrete Cosine Transform (DCT) into the compression and decompression of digital images; for which, the image is divided in square blocks of nxn. Later these blocks are quantized and codified with the Huffman encoding technique.

The computational process is made by means of the Fast Discrete Cosine Transform algorithm (FDCT) [1] programmed in C language. The analyzed images are directly caught by means of a camera and they are sent to a personal computer through a developed video digitizer hardware.
Keywords: Video, Compression, Hardware, DCT.

INTRODUCTION.

The compression and decompression of images, in general terms, require of some type of transformation. The goal of the transformation process is to decorrelate the pixels in the image. The use of one or several transformations will depend on the type of analysis that we want to do to the image [2]. Sometimes it is necessary to subdivide the original image (N x N) in small blocks of size n x n and to apply the transformation to each block. When the image is transformed, a set of coefficients that represent the information contained in the image are obtained, these coefficients are then quantized and coded. By means of the quantization process some of the coefficients are discarded (the coefficients that carry least information) and the rest will be codified. Figure 1 shows a block diagram of the compression and decompression process. Compression is achieved during the quantization of the transformed coefficients not during the transformation step.

A significant factor affecting transform coding error and computational complexity is subimage size. Both the level of compression and computational complexity increase as the subimage size increases. In general, subimage sizes are 8 x 8 and 16 x 16. In this work we have used subimages of 4 x 4.

In the second section of this paper the DCT and the quantization and coded processes are described briefly. In the third section the designed hardware is explained briefly. In fourth section we show some images captured to which compression and decompression process and also subjective and objective tests of quality were applied. Finally we make some conclusions to the presented work.

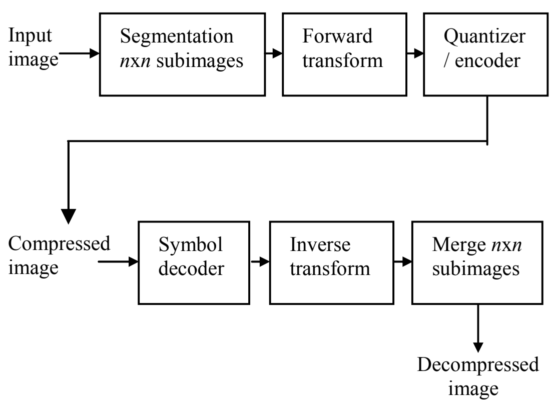

Figure 1. Compression and decompression process.

II. DISCRETE COSINE TRANSFORM.

The two-dimensional Discrete Cosine Transform is define as follows:

$$C(u,v) = \alpha(u)\,\alpha(v) \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y) \;\cdot$$
$$\cdot\ \cos\left[\frac{(2x+1)\,u\,\pi}{2N}\right]\cos\left[\frac{(2y+1)\,v\,\pi}{2N}\right] \quad ..(1)$$

for u, v = 0,1,2,3,.....N - 1, and

$$\alpha(u,v) = \begin{cases} \sqrt{\dfrac{1}{N}} & \text{for } u,v = 0. \\ \sqrt{\dfrac{2}{N}} & \text{for } u,v = 1,2,3,4,...N-1 \end{cases} \quad ..(2)$$

N is the number of elements in each block. The corresponding inverse DCT is:

$$f(x,y) = \sum_{u=0}^{N-1}\sum_{v=0}^{N-1} \alpha(u)\,\alpha(v)\; C(u,v) \;\cdot$$
$$\cdot\ \cos\left[\frac{(2x+1)\,u\,\pi}{2N}\right]\cos\left[\frac{(2y+1)\,v\,\pi}{2N}\right] \quad ..(3)$$

for x, y = 0,1,2,3,.....N - 1.

In order to evaluate the DCT diverse algorithms have been developed, between most efficient is the one of Chan and Ho, the Fast Discrete Cosine Transform (FDCT) [1], which follows a similar logic to the Fast Fourier Transform (FFT), except that it is preceded by a reordering of the input data. In this algorithm the data are separated successively in evens and odds as it is done in the FFT.

The quantization stage in figure 1 selectively eliminates the coefficients that carry least information. These coefficients have the smallest impact on reconstructed subimage quality. The accuracy of the quantized data is in accordance with some preestablished fidelity criterion [3]. In the developed software we have used a L level Lloyd – Max quantizer, the problem is to select the best decision (t_k, k = 1,...,L+1) and reconstruction (r_k; r_1,..., r_L) levels and the input probability density function $p(y)$.

$$t_k = \frac{(r_k + r_{k-1})}{2} \quad .(4)$$

$$r_k = \frac{\int_{t_k}^{t_{k+1}} y\; p(y)\; dy}{\int_{t_k}^{t_{k+1}} p(y)\; dy} \quad ..(5)$$

Equations (4) and (5) have to be resolved simultaneously, given the boundary values t_1 y t_{k+1}. The used probability density functions are the Gaussian, Laplacian and Uniform [4].

Next step in image compression is coded. In numerous applications error-free compression is the only acceptable means of data reduction, which depends of the images under consideration. In order to reduce error in the compression of images, coding redundancy must be reduced. To do so requires construction of a variable-length code that assigns the shortest possible code word to the most probable gray levels. For these reasons we used the Huffman coding [2], which yields the smallest possible number of code symbols per source symbol.

In order to evaluate the amount of error introduced in the compression - decompression process, we make use of equation (6), which represents the root mean square error.

$$e_{rms} = \left[\frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left[\,f(x,y) - f^*(x,y)\right]^2\right]^{1/2} \quad ..(6)$$

$f\,(x,y)$ represents the original image and $f^*(x,y)$ the decompressed image.

III. VIDEO DIGITIZER HARDWARE.

Figure 2 shows the block diagram of all the hardware we designed and we constructed.

* First we have an eight order low-pass Butterworth filter with a high cutoff frequency of 4.2 MHz.

* The voltage limiter (figure 3) is used to protect the A/D converter, since its maximum permissible input voltage is 1.4 V_{pp}.

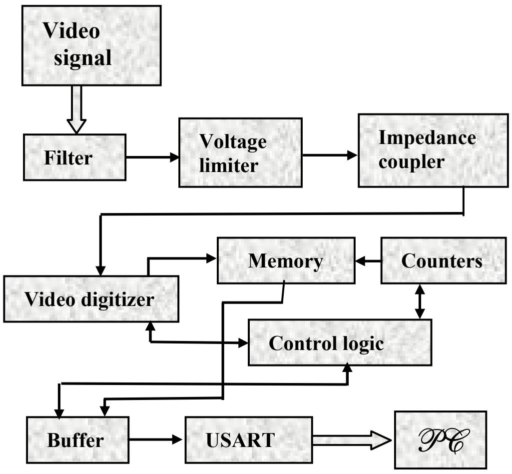

Figure 2. Block diagram of the video digitizer hardware.

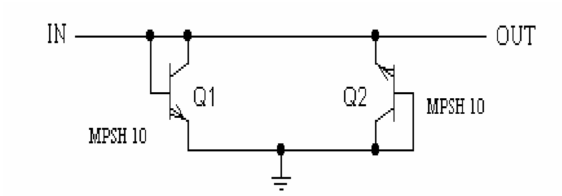

Figure 3. Voltage limiter.

* The impedance coupler avoids signal distortion in the input of the A/D video converter

* The video digitizer has 8 bit gray scale resolution and the pixel clock frequency is 9.8 MHz.

* The counters and the control logic give all the necessary signal for memory addressing and to send the image in memory to a personal computer through the USART 8251A

IV. EXPERIMENTAL RESULTS.

With the program in C language that we have developed it is possible to apply to the images captured with the camera, the process described in figure 1 and to evaluate the error introduced in it.

Subjective and objective tests with different images (original and processed) were realized. In objective tests we could watch that when 1 or 2 bit quantizer is used, it is possible to achieve high compression rates but the processed image has pour quality and a lot of noise. With a 5 or 6 bit quantizer the compession rate is reduced but the quality of the compressed and decompressed image rises.

Subjective tests match objective because images with the best acceptance were those processed with the 5 bit Gaussian or Laplacian quantizer.

Figure 4a shows an original color image captured with our hardware. Figure 4b was obtained by dividing the original image into subimages of 4 x 4 applying each one the DCT and a 2 bit Gaussian quantizer. In this case the image was compressed to 76.6695% of its original size, the obtained mean square error was of 16.5 %. The error image is shown in figure 4c.

Figure 4a. Original image.

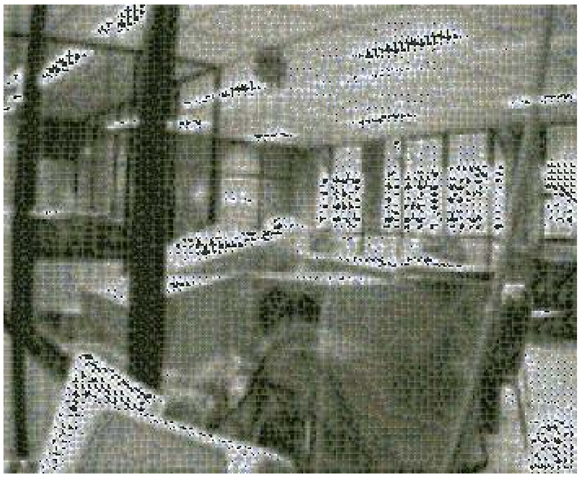

Figure 4b. Compressed and decompressed image. 2 bits Gaussian quantizzer.

If the same image (figure 4a) is processed with a 5 bit Gaussian quantizer the compression obtained is of

72.7595 % respect to its original size and the mean square error is 6.1 %, figure 5a shows the resultant compressed - decompressed image. Figure 5b shows the error image of this process.

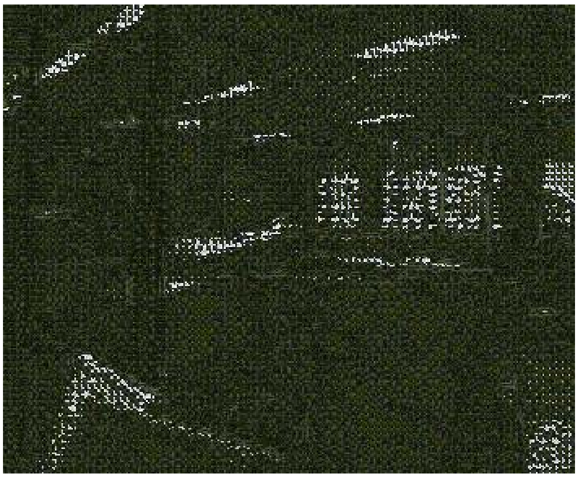

Figure 4c. Error image with a 2 bit Gaussian quantizer.

Figure 5a. Compressed and decompressed image. 5 bit Gaussian quantizzer.

V. CONCLUSIONS.

Of the diverse analyzed images it was observed that with the use of the 5 bit quantizer the smaller amount of error was obtained. The best results were obtained by using the Gaussian and Laplacian quantizers. Due to the use of the FDCT the computational process takes place almost in real time.

In spite of video digitizer cards use is very common, these cards are not designed in our country; this is the reason by which we make this type of developments, therefore we can conclude that hardware developed worked enough good.

Figure 5b. Error image with a 5 bit Gaussian quantizer.

V. REFERENCES.

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