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Hybrid Image Compression using DCT and Fuzzy Logic

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Abstract— Today there has been big advancement in digital technology that has led to the development of various easily usable devices and methods especially in the fields of communications and data transfer to a longer distance. The transmission of data in the form of documents, images, voice etc. is now reachable to all parts of the society and the services are affordable to a larger number of people. An important aspect is data compression and for that matter Image compression, as images form a larger part of data being exchanged over the internet through social networking and messaging sites and apps all over the world. Among all the various kinds of data images and videos constitute the bulkiest data. Thus, need for compressing the image and video files is an important aspect in data communication. In this research work we present a technique for image compression, using Discrete Cosine Transform and Fuzzy Logic Techniques. The algorithm used in this paper is tested along with several images and the results are compared with other techniques. Our method shows an improved performance both in compression ratio as well as image perceptibility.

Keywords: DCT, Fuzzy Transform, Quantization, Entropy, Compression ratio, PSNR, MSE.

I. INTRODUCTION

The development of the higher quality and cheaper image acquisition devices has produced steady increases in both resolution and image size, and a greater consequent for the design of efficient compression techniques [1]. Although the storage capacity and transfer bandwidth has grown accordingly in past years, many applications still require compression. Uncompressed multimedia (graphics, video and audio) data requires storage capacity and transmission bandwidth. Despite the frequent progress in mass-storage density, processor speeds, and the performance of digital communication system, demands for data storage capacity and data-transfer bandwidth. The frequent growth of data intensive multimedia-based web applications have not only maintained the need for more efficient ways to encode signals and images but also have made compression of such signals central to storage and communication technology. The amount of data related with visual information is so large that its storage would require more storage capacity. Although the capacities of several storage media are essential, their access speeds are usually inversely proportional to their storage capacity. The Typical television images produce data rates exceeding 10 million bytes per second. There are other image sources that produce even higher data rates. Storage and/or transmission of such data require large capacity and/or bandwidth, which could be very expensive. Currently image compression is recognized as an “enabling technology”. The Image compression is the natural techniques for handling the increased spatial resolution of today’s imaging sensors and evolving broadcast television standards. Furthermore the image compression plays a vital role in many important and diverse applications , including tele video-conferencing ,remote sensing (the use of satellite images for weather and the other earth –resource applications), document and medical imaging, facsimile transmission, and the control of remotely controlled vehicles in military , space and hazardous waste management applications. The Image Compression represents the problem of reducing the amount of data required to address the digital image. The primary aim of any image compression algorithm is to reduce the number of bits required to store or transmit images without any severe loss of information. Based on this the image compression can be either lossless or lossy. In the lossless image compression algorithm, the original data can be regenerated exactly from the compressed data. And the Lossy compression techniques refer to the loss of information when data is compressed. As a result of this distortion, higher compression ratios are possible as compared to the lossless compression method in the reconstruction of the image. However this high level of compression is accompanied by loss of data and the exact image can’t be reconstructed. There have been a number of techniques which are being used for image compression. JPEG and its advances are most commonly used image compression technique. Researchers have suggested a number of techniques like entropy based techniques, transform based techniques, Predictive coding, run length coding etc. All these methods although focus around reducing the amount of data redundancy in the image file. The data redundancy with respect to an image data can be classified as- coding redundancy(less amount of coding), inter pixel redundancy (finding and eliminating correlated pixel) and psycho-visual redundancy (eliminating no visual information). Among all the techniques the transform based techniques i.e. based on Discrete Cosine Transform and Discrete wavelet Transform have shown the best results over time both in achieving higher compression bandwidth and speed of data transmission. In this paper we present a technique which is a combination of DCT technique and enhanced by Fuzzy logic function. The aim is to give a better compression ratio along with increasing the visual perception quality of the image. Fuzzy logic Technique have been used in various areas involving clustering, data aggregation pattern deduction etc. We are using fuzzy logic in this technique to improve the quality of the compressed image resulted from DCT image compression technique. In the later part of this paper the literature review of various papers has been presented followed by a description of the proposed algorithm and the results thereafter.

II. LITERATURE REVIEW

In this section, a few proposed techniques for image compression, based on lossy, lossless and a mixture of both methods for compression of medical images are studied and analyzed.

The DCT in two dimensions is the core of the JPEG compression [1], this is the most critical module to be designed in hardware JPEG compressor because of its high algorithm complexity. According to [1] there are many algorithms methods to solve the 2-D DCT with a small number of operations. The 2-D DCT has the reparability property. Thus using two1-D DCT calculations it is possible to produce the 2-D DCT results. In an 8x8 input matrix, the first 1-D DCT is used on the matrix lines then the second 1-D DCT is used on the columns of the first 1-D DCT results matrix. This separation reduces the complexity of the calculation.

Victor Sanchez [2] proposed a method for lossless compression of 4-D medical images based on the advanced video coding standard (H.264/AVC) a new context-based adaptive binary arithmetic coder used for lossless compression of the residual and the motion vector data. The proposed method effectively reduces data redundancies in the spatial and temporal dimensions by applying a 4-D search, VSBM, and bidirectional prediction for motion estimation. An average improvement on lossless compression ratio of 13% on real fMRI data when compared to 4D-JPEG2000 and H.264/AVC.

Shaou-Gang Miaou[4] proposed a method that combines the JPEG-LS and an inter frame coding method with motion vectors to increase the compression performance of using JPEG-LS alone. Since the inter frame correlation between the two adjoining images in a medical image sequence is not as high as that in a general video image sequence, the inter frame coding is started only when the inter frame correlation is high enough. With a six capsule endoscope image sequences under test, the suggested method achieves average compression gains of 13.3% and 26.3% over the techniques of using JPEG-LS and JPEG2000 alone, respectively. Similarly, for an MRI image sequence, coding gains of 77.5% and 86.5% are correspondingly obtained.

Janaki. R [5] proposed a technique for image compression which uses the Wavelet-based Image Coding in combination with Huffman encoder for further compression. It aims to determine the best threshold to compress the still image at a particular decomposition level by combining the EZW encoder with Huffman Encoder. The Compression Ratio (CR) and the Peak-Signal to-Noise (PSNR) is determined for the various threshold values ranging from 6 to 60 for decomposition level 8.

Maneesha Gupta [6] presents an analysis of image compression using DCT. They have proposed to develop some simple functions to compute the DCT and to compress images. They went on to comprehend image compression algorithm using Matlab code, and modified to perform better when implemented in hardware description language. They have used IMAP block and IMAQ block of MATLAB to study and analyse the results of Image Compression using DCT and changing co-efficient for compression were developed to show the resulting image and error image from the original images.

Balpreet Kaur [7] has proposed an ROI based method which is compressed with lossless and lossy techniques. The Image Compression is used to compress the image so that it can be further transmitted through the internet with in the low bandwidth. After the compression, when both the images are matched with one another the root mean square error (RMSE) is very low which means that the data loss during compression is negligible that can't be recognized with the human eyes. And also the PSNR is always in the range of 20-40 which is considered as good.

Rohit Kumar Gangwar et. al [8] have presented a performance analysis of image compression using Fuzzy Algorithm. The authors propose an efficient compression technique, which combines fuzzy logic with that of Huffman coding. In this technique while normalizing image pixel, each value of pixel image belonging to that prominent image are characterized and explained. The image is sub divided into pixel which is then showed by a pair of set of approximation. Here an encoding indicate Huffman code which is statistically independent to produce more efficient code for compression and decoding rough fuzzy logic which is used to reconstruct the pixel of image. The technique used here are rough fuzzy logic with Huffman coding algorithm (RFHA). Here the comparison of different image compression techniques with Huffman coding is done and fuzzy logic is used on the Huffman reconstructed image. The Result shows that high compression rates are obtained and visually negligible difference between compressed images and original images.

Neha Gupta [9] presents an image compression method using fuzzy transform. The Approach for Image Compression, based on Fuzzy Transform, is achieved by normalizing the values of its pixels. Any image can be considered as a fuzzy matrix (relation), which is sub-divided in sub-matrices (possibly square) known as blocks. Each block is compressed with the discrete fuzzy transform method of a function in two variables and sequentially it is decompressed via the related inverse fuzzy transform. The decompressed blocks are recomposed for the reconstruction of the image. The proposed method has been compared with the existing methods using performance parameters like MSE (Mean Square Error) and PSNR (Peak Signal to Noise) values.

III. DISCRETE COSINE TRANSFORM

Assume that the data array has finite rectangular support on $[0, N_1, -1] \times [0, N_2 - 1]$, then the 2-D DCT is represent as:

$$X_C(k_1,k_2) \triangleq \sum_{n_1=0}^{N_1-1}\sum_{n_2=0}^{N_2-1} 4x(n_1,n_2)\cos\frac{\pi k_1}{2N_1}(2n_1+1)\cos\frac{\pi k_2}{2N_2}(2n_2+1), \quad (1)$$

For, $(k_1,k_2) \in [0, N_1 - 1]x[0, N_2 - 1], Otherwise, X_C(k_1,k_2) \triangleq 0.$

The mapping between the mathematical values and the colors (gray levels) is same as in the case of DFT. Each basic function occupies a small square; the squares are then arranged into 8 x 8 mosaic

The inverse DCT exists and is given for $(n_1, n_2) \in [0, N_1 - 1] \times [0, N_2 - 1]$ as,

$$x(n_1,n_2) = \frac{1}{N_1 N_2}\sum_{k_1=0}^{N_1-1}\sum_{k_2=0}^{N_2-1} w(k_1)w(k_2)X_C(k_1,k_2)\cos\frac{\pi k_1}{2N_1}(2n_1+1)\cos\frac{\pi k_2}{2N_2}(2n_2+1), \quad (2)$$

Where the weighting function w (k) is given just as in the case of 1-D DCT by

$$w(k) \triangleq \begin{cases} 1/2 & k = 0 \\ 1, & k \neq 0. \end{cases} \quad (3)$$

From eqn (1), we see that the 2-D DCT is a separable operator. So it can be applied to the rows and then the columns, or vice versa. Thus the 2-D theory can be produced by repeated uses of the 1-D theory. In the following subsections we compare the 1-D DCT to 1-D DFT of a symmetrically extended sequence. This not only gives an understanding of the DCT but also enhances its fast calculation. We also present a fast DCT calculation that can avoid the use of complex arithmetic in the usual case where x is a real-valued signal, e.g., an image.

A DCT-based image compression depends on two techniques to reduce the data required and to represent the image [6]. The first is quantization of the DCT image coefficients; the second is entropy coding of the quantized coefficients. The Quantization is the process of reducing the number of possible values of a quantity, thereby deducting the number of bits needed to represent it. Entropy coding is a method for representing the quantized data as compactly as possible. Entropy encoding is a compression technique depends on the idea of denoting fewer bits to represent colors that produce frequently in an image and more bits to those that occur infrequently. The Shannon's entropy equation, allows us to compare an encoding to a theoretical optimum. The Processes with this principle are called entropy encoding. Entropy encoding is used regardless of the media's specific characteristics. The data stream to be compressed is supposed to be a simple digital sequence, and the semantic of the data is avoided. Entropy encoding is an application of lossless encoding as the decompression process reproduces the data completely. The raw data and the decompressed data are similar, no information is distorted.

IV. FUZZY LOGIC

The Fuzzy Logic (FL) is the technique of reasoning that is related to the human reasoning [11]. The approach of FL indicates the way of decision making in humans that involves all intermediate chances between digital values YES and NO [12] . The conventional logic block that a computer can understand takes precise input and generates a definite output as TRUE or FALSE, which is equal to human's YES or NO. The inventor of fuzzy logic, Lotfi Zadeh, founded that unlike computers, the human decision making includes a range of possibilities between YES and NO, such as −

TABLE 1: FUZZY LOGIC VALUES

CERTAINLY YES
POSSIBLY YES
CANNOT SAY
POSSIBLY NO
CERTAINLY NO

The fuzzy logic works on the levels of possibilities and chances of input to obtain the definite output. It can be implemented in systems with different sizes and capabilities ranging from small micro-controllers to large, networked, workstation-based control systems and in software, hardware or a combination of both. The fuzzy logic architecture has the following important parts [13]:

Fuzzification –it convert classical data or crisp data into fuzzy data or Membership Functions (MFs)

Knowledge Base − It stores IF-THEN rules given by the experts.

Fuzzy Inference Process – it combine membership functions with the control rules to obtain the fuzzy output

Defuzzification – it uses various methods to calculate each associated output and put them into a table: the lookup table. Pick up the output from the lookup table based on the current input during the uses.

Figure 1 shows the architecture of a typical Fuzzy Logic System.

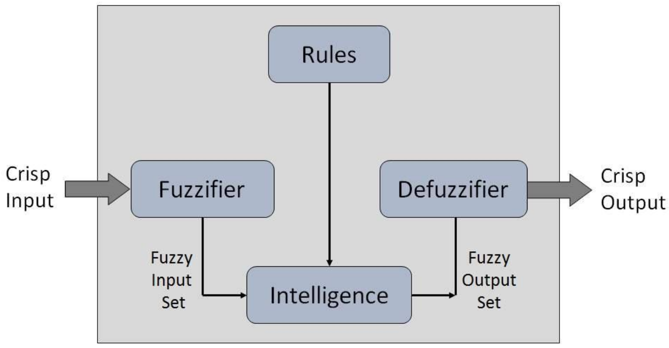


Figure 1: Fuzzy Logic Architecture

V. SYSTEM IMPLEMENTATION

The flowchart of the system designed for the analysis and implementation of the proposed method is given below in Figure 2.

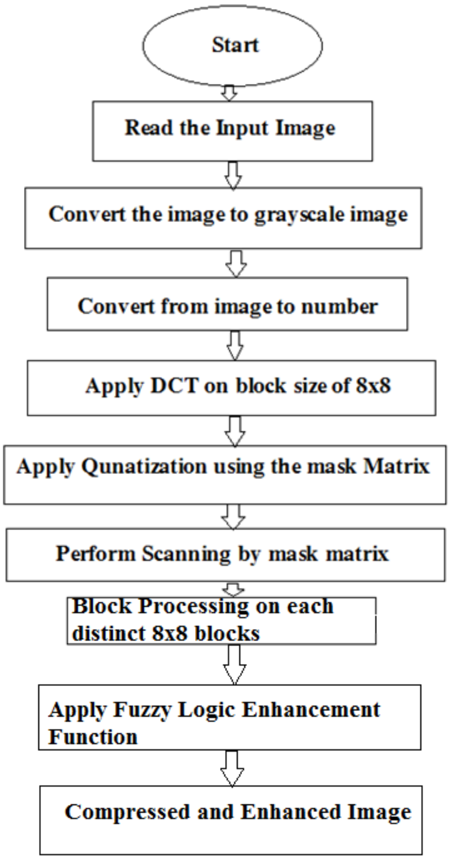
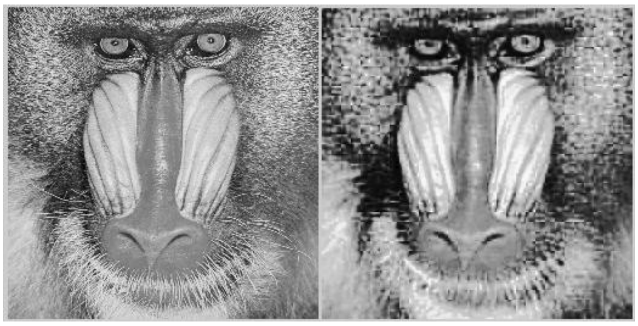


Figure 2: Implementation Block Diagram

This techniques uses a DCT based Fuzzy Logic approach to compress the image. A number of test images are available which has been applied by the researchers working in the Image Processing domain over the several years. This research work also accomplish the standard images for implementation. The image is selected and then converted into the grayscale form using built in MATLAB function. It is then converted into numerical form for numerical analysis. A Discrete Cosine transform is then applied on 8x8 distinct blocks of the image. A mask matrix is created having 8x8 sizes and the quantization of the DCT applied image is obtained. It is processed then block wise to obtained a reduced data size. This image matrix is then passed to the fuzzy logic enhancement function which depending on the type of the image performs enhancement of the given image. Finally the image is converted back to image from the matrix form, which results into DCT compressed and Fuzzy Histogram enhanced Image.

VI. SIMULATION AND RESULTS

The simulation was carried on a number of standard test images like Lena, Barbara, Cameraman etc. which have been used in a number of research works for comparison of various approaches and algorithms, in various works related to Image processing. The images taken are of '.png' image type and of size 256x256. The following are the results of simulation. The simulation result at each step as shown in the block diagram in figure 1, is obtained and shown below figures.



(a) (b)

Figure 3: Baboon (a)Original Image (b) Compressed Image

(a) (b)

Figure 4: Barbara(a)Original Image (b) Compressed Image

(a) (b)

Figure 5: Lena (a)Original Image (b) Compressed Image

Figure 6: Peppers (a) Original Image (b) Compressed Image

The above figures show the simulation results performed on various standard test images. The images have been compressed using DCT technique and then enhanced using Fuzzy Logic Enhancement function [14]. Thus a hybrid approach involving DCT and Fuzzy Logic and DCT have been implemented. The images obtained after compression are perceptively clear and much reduced in disk space as compared to original images. The following table, Table 2 shows the compression ratio analysis of the images.

TABLE 2: COMPRESSION RATIO ANALYSIS

Image	Original Size	Size after Compression	CR
Baboon	**83.3 Kb**	**11.3 Kb**	**7.37:1**
Barbara	**85.6 Kb**	**8.22 Kb**	**10.41:1**
Lena	**163 Kb**	**26.7 Kb**	**6.104:1**
Peppers	**79.9 Kb**	**9.03 Kb**	**8.848:1**

Compression rate shows that how much an image can be compressed from its original size. There are two error metrics which is used to compare the quality of image compression, that are known as MSE and PSNR. The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error. Lower the value of MSE lowers the error.

$$\text{MSE}=\frac{1}{MN}\sum_{i=1,j=1}^{M,N} I(\text{i,j})^2 - \text{C(i,j)}^2 \qquad (4)$$

Where M,N represent the width and height pixel values I is original image and C is compressed image.

The PSNR values are calculated using the following equation:

$$\text{PSNR}=10\log_{10}\frac{(2*n-1)2}{MSE} \qquad (5)$$

Where n represents the no. of bits per pixel.

The below table represents the values of PSNR and MSE for various images.

TABLE 3: PERFORMANCE EVALUATION

IMAGE	MSE	PSNR
BABOON	**0.0169**	**40.2681**
BARBARA	**0.0057**	**50.9109**
LENA	**0.0018**	**62.3790**
PEPPERS	**0.0044**	**51.7580**

VII. CONCLUSION

Image Compression is an important aspect in multimedia communication. We have presented a hybrid technique using DCT and Fuzzy logic for compression of image files. The algorithm was tested on a number of test images and was found to give good results both in terms of image compression ratio and the quality of image. The MSE was also found to be lower which is an important performance parameter and the lower value means there is little difference between original and compressed images. The method can be extended further with other image types like true-color images and video files.

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