Improved 2-D DCT Image Compression Using optimal compressed value

Sanjeev Singla[#1],Abhilasha Jain[*2]
[#]CSE,PTU GZS Campus
Bathinda,India
[1]sanjeev_singla87@yahoo.co.in
[*]HOD CSE,PTU GZS Campus
Bathinda,India
[2]abd_jain@rediffmail.com

***Abstract*-This paper presents a study on image compression algorithms. The goal is to find the existing work in the field of image compression algorithms. Various high quality papers are selected for evaluation. The benefits and limits of the compression techniques also discussed in this paper. The overall objective is to find an analytical assumption that why lossy compression is useful and also how we can enhance it by using improved DCT compression.**

I. INTRODUCTION

In recent years, the development and demand of multimedia product grows increasingly fast, contributing to insufficient bandwidth of network and storage of memory device. Therefore, the theory of data compression becomes more and more significant for reducing the data redundancy to save more hardware space and transmission bandwidth. In computer science and information theory, data compression or source coding is the process of encoding information using fewer bits or other information-bearing units than a uuencoded representation. Compression is useful because it helps reduce the consumption of expensive resources such as hard disk space or transmission bandwidth [1]. In digital image compression, three basic data redundancy can be identified and exploited: coding redundancy, interpixel redundancy and psych visual redundancy. Data compression is achieved when one or more of these redundancies are reduced or eliminated [2]. An image's file size can be reduced with or without a loss in quality of the image; these are called lossy compression and lossless compression, respectively. Image compression is useful when a computer user wishes to minimize required storage space or maximize data transfer rates of an image.

The first type of image compression is lossy compression. A user seeking to dramatically reduce an image file size may opt for a lossy compression method if some reduction in image quality is worth a significant reduction in file size. Pictures and videos from digital cameras are examples of digital files that are commonly compressed using lossy methods. A user will not be able to restore the original image because there will be compression artifacts, or irreversible alterations, in the image. A simple method of lossy image compression is to reduce the color space to a smaller set of colors. Color spaces can range from only eight distinct colors to millions of colors. The larger the color space, the more data is required to specify a particular color. Converting an image to gray scale, or to shades of gray, is a similar lossy image compression technique.

Lossless image compression is any method of reducing an image's file size without sacrificing information about the image an identical image to the original can always be retrieved. Lossless forms of data compression are necessary when reductions in quality are deemed unacceptable. Medical imaging, technical drawings, and astronomical observations typically use lossless compression techniques. One loseless image compression method is called run-length encoding. Often, simple images have many repetitive pixels, or small points of color. For example, in an image with a black background, the entire top row of pixels may be black. The run-length encoding method stores this string of black pixels in two values: one for the color and one for the number of pixels in the string. This method can store the same amount of information with much less data.

A. *Scope of the paper:*The overall goal of the work is to measure the performance of the proposed strategy over the existing techniques of compression algorithms.
   - This research work deals with reducing the amount of data required to represent the digital images.

- This research work does not deal with other operations that can be applied on the digital images.
- As 2DCT comes up with some extra computation so DCT overheads are also considered in this thesis.
- This research work also deals with the process to collect, analyse, and evaluate the digital images to prove the effectiveness and efficiency of the proposed strategy.
- Different type of tests will be implemented using proposed algorithm to test various aspects of the image compression algorithms.
- Visualization of the experimental results and drawing appropriate performance analysis.
- Appropriate conclusion will be made based upon performance analysis.
- For future work suitable future directions will be drawn considering limitations of existing work.

Throughout the research work emphasis has been on the use of either open source tools & technologies or licensed software.

1) *Objectives of this research work:*

- The primary objective is to reduce MEAN SQUARE ERROR (MSE) of compressed images using proposed technique than existing technique. The MSE represents the cumulative squared error between the compressed and the original image. The MSE can be evaluated using the following equation:

$$MSE = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{M * N}$$

  In the previous equation, M and N are the number of rows and columns in the input images, respectively. The lower the value of MSE, the lower the error.
- Another objective is to maximize the PEAK SIGNAL-TO-NOISE RATIO (PSNR) between images. The PSNR block computes the peak signal-to-noise ratio, in decibels, between two images. This ratio is often used as a quality measurement between the original and a compressed image. The higher the PSNR, the better the quality of the compressed, or reconstructed image. The MSE and the Peak Signal to Noise Ratio (PSNR) are the two error metrics used to compare image compression quality. PSNR represents a measure of the peak error. To compute the PSNR, the block first calculates the MSE. The block computes the PSNR using the following equation:

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right)$$

R is the maximum fluctuation in the input image data type. For example, if the input image has a double-precision floating-point data type, then R is 1. If it has an 8-bit unsigned integer data type, R is 255, etc.

II. LITERATURE SURVEY

Priyanka Singh Tejyan and Priti Singh has studied a novel approach to 2d-dct & 2d-dwt based jpeg image compression [3]. Image compression using wavelet transforms results in an improved compression ratio. Wavelet transformation is the technique that provides both spatial and frequency domain information. These properties of wavelet transform greatly help in identification and selection of significant and non-significant coefficients amongst the wavelet coefficients. DWT (Discrete Wavelet Transform) represents image as a sum of wavelet function (wavelets) on different resolution levels. So, the basis of wavelet transform can be composed of function that satisfies requirements of multi resolution analysis. The choice of wavelet function for image compression depends on the image application and the content of image.

Prashant Chaturvedi et al have been researched a novel VLSI based architecture for computation of 2D-DCT image compression [4]. Data image compression is the reduction of redundancy in data representation in order to achieve reduction in storage cost. The Implementation and Optimization of FPGA based 2DDCT (discrete Cosine Transform) with Quantization and Zigzag with parallel pipelining using VHDL.

Nageswara Rao Thota and Srinivasa Kumar Devireddy have studied the Image Compression Using Discrete Cosine Transform [5]. *Image compression is the application of data compression on digital images. Image compression can be lossy or lossless. The discrete cosine transform (DCT) is a mathematical function that transforms digital image data from the spatial domain to the frequency domain.*

T. Pradeepthi and Addanki Purna Ramesh have researched pipelined architecture of 2D-DCT, quantization and zigzag process for jpeg image compression using VHDL [6]. The architecture and VHDL design of a Two Dimensional Discrete Cosine Transform (2D-DCT) with Quantization and zigzag arrangement. This architecture is used as the core and path in JPEG image compression hardware. The 2D- DCT calculation is made using the 2D- DCT Separability property, such that the whole architecture is divided into two 1D-DCT calculations by using a transpose buffer. ***Abhishek Kaushik and Maneesha Gupta*** have studied on the analysis of image compression algorithms [7]. Image compression is the application of Data compression on digital images. The discrete cosine transform (DCT) is a technique for converting a signal into elementary frequency components. It is widely used in image compression. Here some simple functions developed to compute the DCT and to compress images. An image compression algorithm was comprehended using MATLAB code, and modified to perform better when implemented in hardware description language.

Vikrant Kumar has researched the design & implementation of 2D DCT/IDCT using XiLinx FPGA [8]. The design of two-dimensional discrete cosine transforms (DCT) architecture for Multimedia communication applications has described in it. It is basic transformation for coding method to transform the image formation from spatial domain to frequency domain in compact form.

Anitha S has studied the 2d image compression technique-a survey [9]. Advanced imaging requires storage of large quantities of digitized data. Due to the constrained bandwidth and storage capacity, images must be compressed before transmission and storage. However the compression will reduce the image fidelity, especially when the images are compressed at lower bitrates. The reconstructed images suffer from blocking artifacts and the image quality will be severely degraded under the circumstance of high compression ratios.

P. Subramanian has described the VLSI implementation of fully pipelined multiplierless 2D DCT/IDCT architecture for JPEG [10]. The Discrete Cosine transform is widely used as the core of digital image compression. Discrete cosine transforms attempts to de-correlate the image data. After decor relation, each transform coefficient can be encoded independently without losing compression efficiency.

H. Anas has studied FPGA implementation of a pipelined 2D-DCT and simplified quantization for real-time applications [11]. The Discrete Cosine Transform (DCT) is one of the most widely used techniques for image compression. Several algorithms are proposed to implement the DCT-2D.

A.K.T. Tan has researched in the improving mobile color 2D-barcode JPEG image readability using DCT coefficient distributions [12]. Two dimensional (2D) barcodes are becoming a pervasive interface for mobile devices, such as camera smart phones. Often, only monochrome 2D-barcodes are used due to their robustness in an uncontrolled operating environment of smart phones. Nonetheless, an emerging use of color 2D-barcodes for camera smart phones. Most smart phones capture and store such 2D-barcode images in the baseline JPEG format. As a lossy compression technique, JPEG does introduce a fair amount of error in the captured 2D-barcode images.

V.K. Nath has illustrated on the comparison of generalized Gaussian and Cauchy distributions in modeling of dyadic rearranged 2D DCT coefficients [13]. The dyadic rearrangement of block two-dimensional Discrete Cosine Transform (2D DCT) coefficients when used with zero tree quantizers show comparable performance with that of discrete wavelet transform based methods for image compression applications. Recently, showed result of Generalized Gaussian distribution better models the statistics of subband rearranged 2D DCT coefficients compared to Gaussian, Laplacian and Gamma distributions.

K.T. Tan has researched the JPEG compression of monochrome 2D-barcode images using DCT coefficient distributions [14]. Two dimensional (2D) barcodes are becoming a pervasive interface for mobile devices, such as camera phones. Often, only monochrome 2D-barcodes are used due to their robustness in an uncontrolled operating environment of camera phones.

E.D. Kusuma has studied in the FPGA implementation of pipelined 2D-DCT and quantization architecture for JPEG image compression [15]. Two dimensional DCT takes important role in JPEG image compression. Architecture and VHDL design of 2-D DCT, combined with quantization and zig-zag arrangement, has described. The architecture is used in JPEG image compression. DCT calculation used in this paper is made using scaled DCT. The output of DCT module needs to be multiplied with post-scaler value to get the real DCT coefficients. Post-scaling process is done together with quantization process. 2-D DCT is computed by combining two 1-D DCT that connected by a transpose buffer.

D. Jessintha has researched the energy efficient, architectural reconfiguring DCT implementation of JPEG images using vector scaling [16]. The DCT implementation of JPEG images using discrete cosine transform (DCT). The proposed method aims at reducing the power consumption which by application of vector scaling on DCT. This will be very useful for image compression and transmission applications.

III. PROBLEM FORMULATION

A. *Problem Definition:*In this research work a hybrid technique will be proposed which will use the feature of 2DCT and compress the images in efficient manner. As in previous work not much metrics were calculated to evaluate the performance of compressed vs. original images. So to improve compression ration a new technique will be developed which will uses lossy compression along with 2DCT to compute better results.Also different image metrics for quality as well as compression measurement will be used to evaluate the performance of proposed algorithm.Proposed algorithm will be implemented in Matlab and uses the feature of image processing tool box.

1) *Research methodology:*To attain the objective, step-by-step methodology is used in this research work. Subsequent are the different phases which are used to accomplish this work.

- *Orientation:*This research work starts with the orientation in the area of cloud computing. By consulting websites of current cloud service offerings, reading news articles, participating in seminars and discussing with the experts. This research employs a structured method to obtain high quality information, called a related work.
- *Literature survey:* To explore the available knowledge on the area of digital image processing,

DCT and 2DCT, literature survey will be conducted using a systematic approach. High quality papers are selected to explore the existing techniques.

- *Proposed algorithm implementation:*The 2D-DCT can be computed by performing 1D-DCT for rows and columns separately as shown in the figure 2 below. The left most top corner value in the matrix of 8-by-8 is called as a "DC value" which is the average value of the block. All other values in the block are "AC values" which represents changes in a block across its height and width. The main idea behind doing the DCT is to separate out high and low frequency information in the image so that it becomes easy to eliminate the high frequency components without losing the low frequency components.

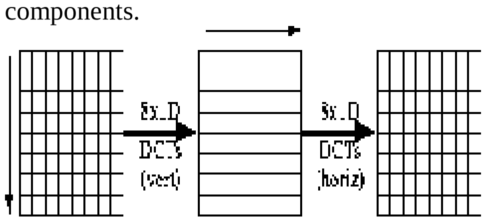

Fig.1 Method for computing 2D-DCT using 1D-DCT

In the mathematical form, DCT for a given block of size N x N can be given by,

$$F_{uv} = \frac{1}{4} C_v C_u \sum_{y=0}^{N-1}\sum_{x=0}^{N-1} S_{yx} \cos\left(v\pi \frac{2y+1}{2N}\right) \cos\left(u\pi \frac{2x+1}{2N}\right)$$

$$C_u = \begin{cases} \frac{1}{\sqrt{2}} & \text{if } u = 0 \\ 1 & \text{else} \end{cases}$$

$$C_v = \begin{cases} \frac{1}{\sqrt{2}} & \text{if } v = 0 \\ 1 & \text{else} \end{cases}$$

- *Performance analysis:*In order to do performance analysis, comparisons will be made with different existing methods. Comparisons table and diagrams will be made based upon the outcomes of the experimental results. Different image quality metrics will be considered to evaluate the performance of proposed metric.

IV. THE DISCRETE COSINE TRANSFORM (DCT)

The discrete cosine transform (DCT) helps separate the image into parts (or spectral sub-bands) of differing importance (with respect to the image's visual quality). The DCT is similar to the discrete Fourier transform: it transforms a signal or image from the spatial domain to the frequency domain.

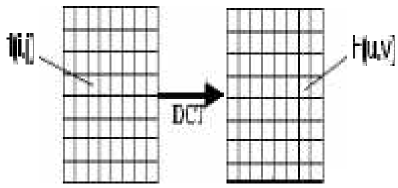

Fig. 2 Transformation from spatial to frequency domain.

A. *DCT Encoding:*The general equation for a 1D (*N* data items) DCT is defined by the following equation:

$$F(u) = \left(\frac{2}{N}\right)^{\frac{1}{2}} \sum_{i=0}^{N-1} \Lambda(i).\cos\left[\frac{\pi.u}{2.N}(2i+1)\right] f(i)$$

And the corresponding ***inverse*** 1D DCT transform is simple $F^{-1}(u)$, i.e.: where

$$\Lambda(i) = \begin{cases} \frac{1}{\sqrt{2}} & \text{for } \xi = 0 \\ 1 & \text{otherwise} \end{cases}$$

The general equation for a 2D (*N* by *M* image) DCT is defined by the following equation:

$$F(u,v) = \left(\frac{2}{N}\right)^{\frac{1}{2}} \left(\frac{2}{M}\right)^{\frac{1}{2}} \sum_{i=0}^{N-1}\sum_{j=0}^{M-1} \Lambda(i).\Lambda(j).\cos\left[\frac{\pi.u}{2.N}(2i+1)\right] \cos\left[\frac{\pi.v}{2.M}(2j+1)\right].f(i,j)$$

And the corresponding ***inverse*** 2D DCT transform is simple $F^{-1}(u,v)$, i.e.: where

$$\Lambda(\xi) = \begin{cases} \frac{1}{\sqrt{2}} & \text{for } \xi = 0 \\ 1 & \text{otherwise} \end{cases}$$

The basic operation of the DCT is as follows:

- The input image is N by M;
- f(i,j) is the intensity of the pixel in row i and column j;
- F (u,v) is the DCT coefficient in row k1 and column k2 of the DCT matrix.
- For most images, much of the signal energy lies at low frequencies; these appear in the upper left corner of the DCT.
- Compression is achieved since the lower right values represent higher frequencies, and are often small -

small enough to be neglected with little visible distortion.
- The DCT input is an 8 by 8 array of integers. This array contains each pixel's grey scale level;
- 8 bit pixels have levels from 0 to 255.
- Therefore an 8 point DCT would be:

Where

$$\Lambda(\xi) = \begin{cases} \frac{1}{\sqrt{2}} & \text{for}\xi = 0 \\ 1 & \text{otherwise} \end{cases}$$

The output array of DCT coefficients contains integers; these can range from -1024 to 1023.It is computationally easier to implement and more efficient to regard the DCT as a set of **basis functions** which given a known input array size (8 x 8) can be precomputed and stored. This involves simply computing values for a convolution mask (8 x8 window) that get applied (summ values x pixelthe window overlap with image apply window accros all rows/columns of image). The values as simply calculated from the DCT formula. The 64 (8 x 8) DCT basis functions are illustrated in Fig.3.

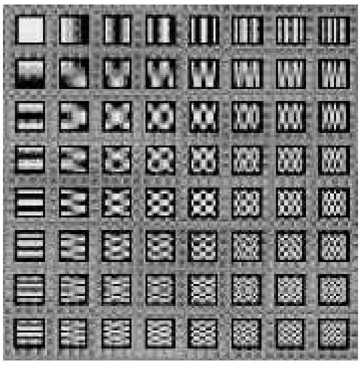

Fig. 3 DCT Basis Functions.

1) *DCT Basis Function:*Why DCT not FFT? DCT is similar to the Fast Fourier Transform (FFT), but can approximate lines well with fewer coefficients.

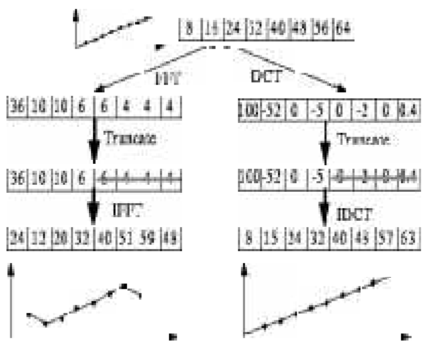

Fig. 4 Why DCT not FFT?

V. DCT/FFT COMPARISON

Computing the 2D DCT Factoring reduces problem to a series of 1D DCTs:

- apply 1D DCT (Vertically) to Columns
- Apply 1D DCT (Horizontally) to resultant Vertical DCT above.
- Or alternatively horizontal to Vertical.

The equations are given by:

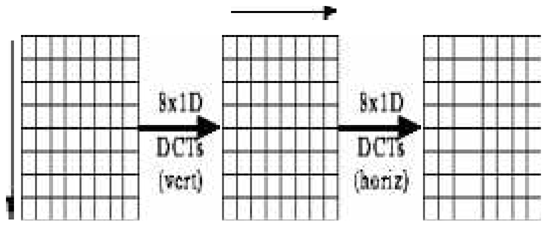

Fig. 5 Computation of 2-D DCT

Most software implementations use fixed point arithmetic. Some fast implementations approximate coefficients so all multiplies are shifts and adds.

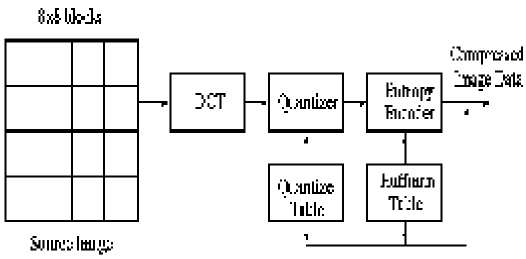

Fig. 6 Representation of obtaining compressed image data from source image.

The discrete cosine transform (DCT) is used to transform a signal from the spatial domain into the frequency domain. The reverse process, that of transforming a signal from the frequency domain into the spatial domain, is called the inverse discrete cosine transform (IDCT). A signal in the frequency domain contains the same information as that in the spatial domain. The order of values obtained by applying the DCT is coincidentally from lowest to highest frequency. This feature and the psychological observation that the human eye and ear are less sensitive to recognizing the higher-order frequencies leads to the possibility of compressing a spatial signal by transforming it to the frequency domain and dropping high-order values and keeping low-order ones. When reconstructing the signal, and transforming it back to the spatial domain, the results are remarkably similar to the original signal. This process, with a few extra bells and whistles and slightly modified versions of DCT, is the essence behind jpeg, mpeg, and mp3 compression. Here, we look at a simplified case of compression using the DCT and IDCT without bells and whistles. The process:

- X = Apply DCT to a sequence of values.
- X' = Drop a portion of high-order values from X.
- X" = Apply IDCT to X'
- Draw X" and observe the similarity to the original X.

For the purpose of comparison, we drop high-order values in the following ranges:

- 1/2 of all values, resulting in 50% compression.
- 3/4 of all values, resulting in 75% compression.
- 7/8 of all values, resulting in 87.5% compression.

A. Compression:

- In 1-dimensional compression we apply the above process to only one dimension (the horizontal) for now. Each row is considered as a sequence of values, and undergoes a DCT and an IDCT.

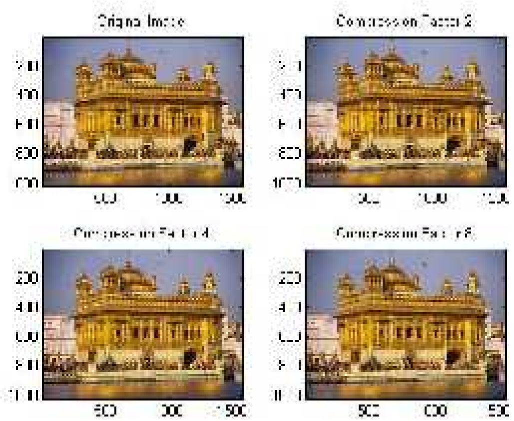

Fig. 7 Representation of 1-D Compression

- In 2-dimensional compression:In addition to the previous compression of rows, we can compress columns of data as well. The compression rate for the entire image then increases by some factor:
    - o 50% horizontal, 50% vertical = 25% total
    - o 75% horiztonal, 75% vertical = 93.75% total
    - o 87.5% horizontal, 87.5% vertical = 98.44% total

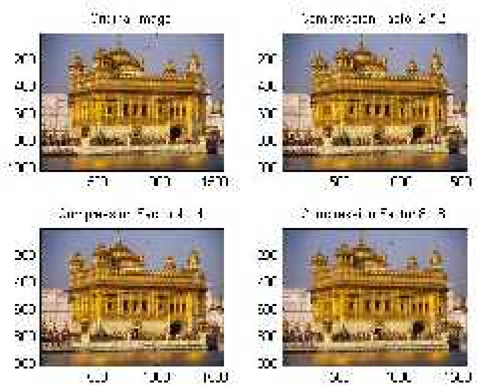

Fig. 8 Representation of 2-D Compression

1) *Discussion:*The compression shown here is somewhat simplistic - we compressed full rows separately from full columns. Typically, images are compressed in macroblocks of 8 rows by 8 columns, where each block is linearized into a one-dimensional vector. This approach is certainly better, since it leverages localization of color within a macroblock. It is unlikely that color within an 8x8 block changes dramatically, and thus high compression rates can be achieved while retaining quality of detail. When does compression fail? Frequently changing colors in dense spaces cannot be represented well with few coefficients. For example, a row of pixels interchanging between black and white pixel-by-pixel, is viewed as a high frequency in the frequency domain. However, a high frequency cannot be represented with few coefficients, and thus dropping high-order coefficients from the DCT removes the necessary detail. This is also the reason why diagrams are not compressed using jpeg compression.

- In 3-D dimension compression,Out of curiosity, we will compress the 3rd dimension of the image, i.e. the 3-value color for each pixel. Because this requires computing the DCT for rows*columns vectors, and such computation is lengthy, we will resize the original image. A simple algorithm for resizing by factors of 2 is the nearest neighbor algorithm. For a half-size in both dimensions, we simply remove every other pixel in rows and columns. This is easily done in Matlab:

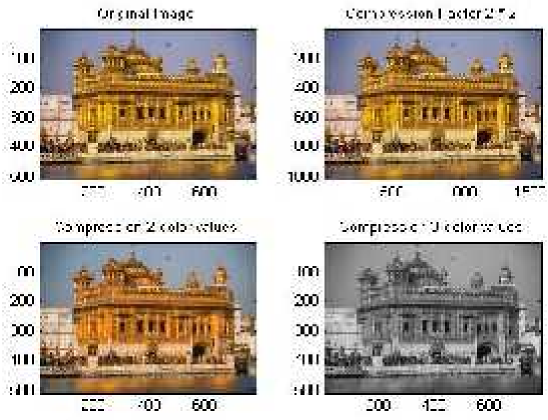

Fig. 9 Representation of 3-D Compression

VI. PERFORMANCE RESULTS

TABLE I

The Table I is showing the result of DCT in 1D by taking the different images at different factors.

Name	**Original image**	**Compression factor 2**	**Compression factor 4**	**Compression factor 8**
Harimandir.jpg	184 KB	44.6 KB	68.6 KB	63.7 KB
Mri.bmp	216 KB	54.7 KB	78.4 KB	75.3 KB
Lena.jpg	300 KB	69.4 KB	110.2 KB	104.5 KB
Tajmehal.jpg	360 KB	87.3 KB	127.7 KB	123.2 KB
Baby.jpg	411 KB	93.66 KB	143.6 KB	140.4 KB
Hill.jpg	500 KB	120.71 KB	168.3 KB	164.9 KB
Water.jpg	600 KB	140 KB	189.2 KB	186.1 KB

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