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# Image compression using discrete cosine transform and discrete wavelet transform

## Pragati Upadhyay and Archana Singh

**Abstract**
The large amount of digital data being created, store and transferred over the internet calls for optimum usage of available data storage capabilities. Images forms the bulk of the data and thus study and application of image compression becomes inevitable. In this research work, a thorough investigation into the image compression paradigm has been presented. The two commonly used techniques of image compression viz. Discrete cosine based Image compression and Discrete Wavelet based Image Compression techniques have been presented here. The techniques have been discussed by comparing the performance of the algorithm on a number of images. The images used are standard images of varying sizes. The techniques have been applied successfully and the results of compression using both the techniques have been compiled. The comparison shows as given in the results chapter that for the same input image the compression in DCT technique is more than the DWT technique. However, the quality of the image decreases. There always lies a tradeoff between the compression ratio and perceptual quality of the image obtained and it largely depends on the usage to decide the priority of which method to choose over the other. If the focus and usage is entirely on compression and image quality is a less important factor, then the preferred method should be DCT as described in this thesis. However, if the quality of image is also to be maintained while compressing into smaller disk size, then the DWT based compression technique must be employed.

**Keywords:** DCT, DWT and image compression techniques

## Introduction
Modern media is overwhelming with graphics such as images and movies. Constraints on bandwidth and memory space create trade-offs between the size and quality of images. The increasing demand for multimedia content such as digital images and video has led to great interest in research into compression techniques. The development of higher quality and less expensive image acquisition devices has produced steady increases in both image size and resolution, and a greater consequent for the design of efficient compression systems Jain (1989) [1]. Although storage capacity and transfer bandwidth has grown accordingly in recent years, many applications still require compression.

## Understanding Compression
If image data can be represented as an array, then each number represents an intensity value at a particular location in the image and is called as a picture element or pixel. Pixel values are usually positive integers and can range between 0 to 255. This means that each pixel of a BW image occupies 1byte in a computer memory. In other words, we say that the image has a grayscale resolution of 8 bits per pixel (bpp). On the other hand, a colour image has a triplet of values for each pixel one each for the red, green and blue primary colours. Hence, it will need 3 bytes of storage space for each pixel.

## Data Compression Model
A data compression system mainly consists of three major steps and that are removal or reduction in data redundancy, reduction in entropy, and entropy encoding. A typical data compression system can be labeled using the block diagram shown in Figure 2 It is performed in steps such as image transformation, quantization and entropy coding. An image contains low visual information in its high frequencies for which heavy quantization can be done in order to reduce the size in the transformed representation. Entropy coding follows to further reduce the redundancy in the transformed and quantized image data.

## Advantages of Data Compression

The main advantage of compression is that it reduces the data storage requirements. It also offers an attractive approach to reduce the communication cost in transmitting high volumes of data over long-haul links via higher effective utilization of the available bandwidth in the data links. This significantly aids in reducing the cost of communication due to the data rate reduction. The advantages of data compression will enable more multimedia applications with reduced cost.

## Disadvantages of data compression

Data compression has some disadvantages too, depending on the application area and sensitivity of the data. For example, the extra overhead incurred by encoding and decoding processes is one of the most serious drawbacks of data compression, which discourages its usage in some areas. This extra overhead is usually required in order to uniquely identify or interpret the compressed data. Data compression generally reduces the reliability of the data records Jain 1989 [1]. In many hardware and systems implementations, the extra complexity added by data compression can increase the system‘s cost and reduce the system‘s efficiency, especially in the areas of applications that require very low-power VLSI implementation Penebaker and Mitchell (1993) [7].

## Lossless compression

In lossless image compression algorithm, the original data can be recovered exactly from the compressed data. It is used generally for discrete data such as text, computer generated data, and certain kinds of image and video information. Lossless compression can achieve only a modest amount of compression of the data and hence it is not useful for sufficiently high compression ratios. GIF, Zip file format, and Tiff image format are popular examples of a lossless compression [ISO/IEO WD 2000 and Penebaker and Mitchell 1993] [7].

## Lossy compression

Lossy compression techniques refer to the loss of information when data is compressed. As a result of this distortion, must higher compression ratios are possible as compared to the lossless compression in reconstruction of the image. 'Lossy' compression sacrifices exact reproduction of data for better compression. It both removes redundancy and creates an approximation of the original.

**Table 1:** RGB color examples

| Colour | Red | Blue | Green |
|---|---|---|---|
| Black | 0 | 0 | 0 |
| White | 255 | 255 | 255 |
| Yellow | 255 | 255 | 0 |
| Dark Green | 0 | 100 | 0 |

The size of the row (M) and column (N) gives the size (or resolution) of M X N image. A small block (8 X 8) of the image is indicated at the lower right corner in the form of matrix. Each element in the matrix represents the dots of the image. Each dot represents the pixel value at that position Martucci *et al.*, (1997) [5].

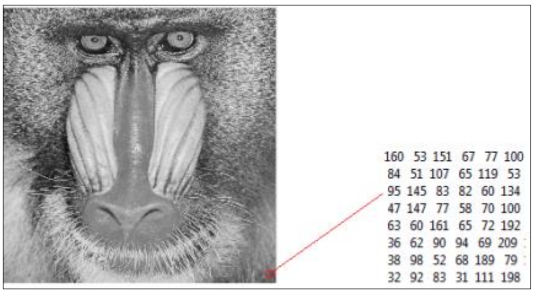



**Fig 1:** Digital representation of an image

Where Y represents a monochrome compatible luminance component, and *CB*, *CR* represent chrominance components containing color information. Most of image/video coding standards adopt *YCBCR* color format as an input image signal Martucci *et al.*, (1997) [5]. Figure 3 shows a block diagram of the color space conversion. Each of the three components (Y, Cb, and Cr) is input to the coder. The PSNR is measured for each compressed component (Yout, Cbout, and Crout) just as we do for gray scale images.

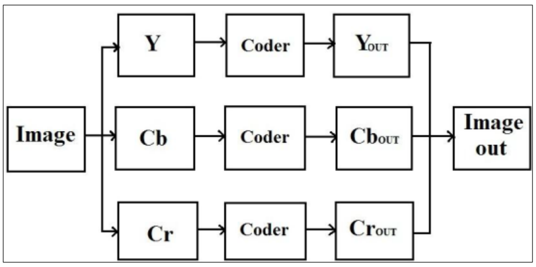



**Fig 2:** Block diagram of the color image compression algorithm.

## Redundancy

Redundancy different amount of data might be used. If the same information can be represented using different amounts of data, and the representations that require more data than actual information, is referred as data redundancy. In other words, Number of bits required to represent the information in an image can be minimized by removing the redundancy present in it Martucci *et al.*, (1997) [5].

Coding

Various coding techniques are used to facilitate compression. Here are pixel coding, predictive coding and transform coding will be discussed Oppenheim and Schafer (1989) [2]

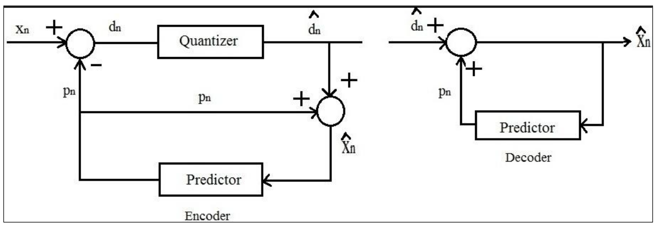



**Fig 3:** DPCM coder

**DPCM Coder**

## Transform-based Image Compression

Transform refers to changing the coordinate basis of the original signal, such that a new signal has the whole information in few transformed coefficients. The processing of the signals in the transform domain is more efficient as the transformed coefficients are not correlated Martucci *et al.*, (1997) [5]. A popular image compression framework is the transform based image compression as shown in below figure.

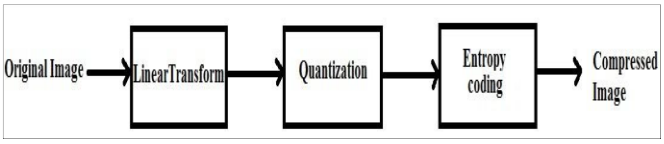



**Fig 4:** Transform based Image Compression Encoder

**Transform based Image compression encoder**

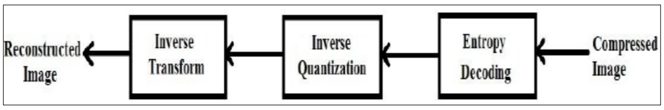



**Fig 5:** Transform based Image Compression Encoder

### Transform based Image Compression Encoder

The first step in the encoder is to apply a linear transform to remove redundancy in the data, followed by quantizing the transform coefficients, and finally entropy coding then we get the quantized outputs. After the encoded input image is transmitted over the channel, the decoder reverse all the operations that are applied in the encoder side and tries to reconstruct a decoded image as close as to the original image Mallat and Falzon (1997) [6].

### Discrete Cosine Transform

DCT is an orthogonal transform, the Discrete Cosine Transform (DCT) attempts to décor relate the image data. After décor relation each transform coefficient can be encoded independently without losing compression efficiency. The value of quantization is inversely proportional to quality of reconstructed image, better mean square error and better compression ratio Fischer *et al.*, (1992) [8].

$Q_{matrix}$ =

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 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 |

**Fig 6:** JPEG Quantization Table

### JPEG Quantization Table

Q matrix is chosen, with a Quality level of 50, Q50matrix gives both high compression and excellent decompressed image. By using Q10 we get significantly more number of 0‘s as compared to Q90. After Quantization, all of the quantized coefficients are ordered into the zigzag sequence. The zigzag can be done in the below manner as shown in the figure.

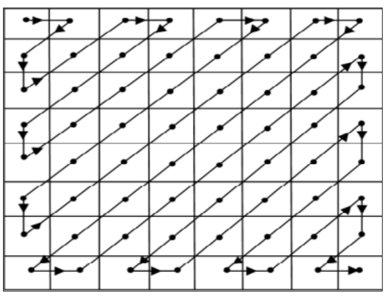


**Fig 7:** Zig Zag Scanning of DCT Coefficients

Now encoding is done and transmitted to the receiver side in the form of one dimensional array. This transmitted sequence saves in the text format. The array of compressed blocks that constitute the image is stored in a drastically reduced amount of space. Further compression can be achieved by applying appropriate scaling factor Rao and Yip (1990).

### Discrete Wavelet Transform (DWT)

Wavelets are a mathematical tool for changing the coordinate system in which we represent the signal to another domain that is best suited for compression. Wavelet based coding is more robust under transmission and decoding errors. Due to their inherent multi resolution nature, they are suitable for applications where scalability and tolerable degradation are important Doubechies 1992.

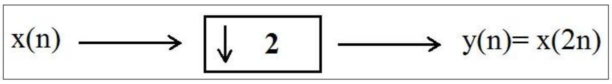



**Fig 8:** Decimator

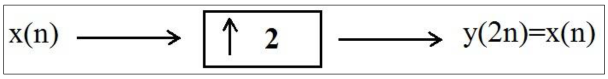



**Fig 9:** Interpolator

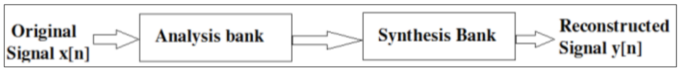



**Fig 10:** Filter bank

### Analysis bank

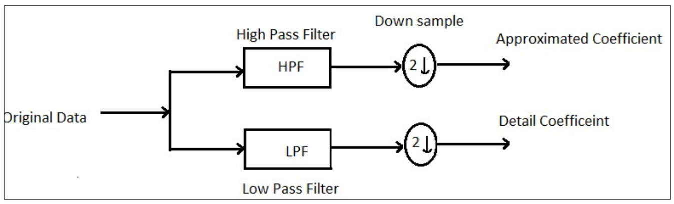



**Fig 11:** 1-D forward DWT

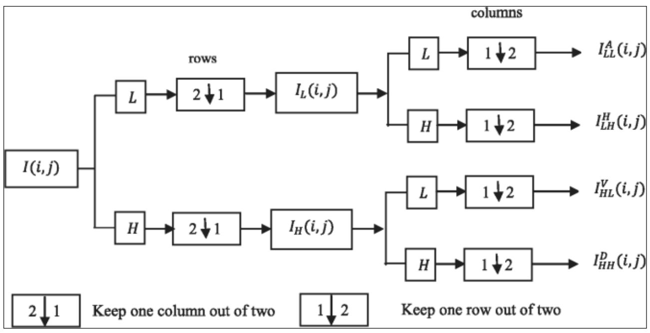



**Fig 12:** Block Diagram 2D-DWT

### Materials and Methods

### Discrete Cosine Transform Implementation:

As explained in the below diagram, the Discrete Cosine Transform procedure is shown in figure 3.1. The input image is preprocessed and converted to grayscale format. First the whole image is loaded to the encoder side, then we do RGB to GRAY conversion after that whole image is divided into small NXN blocks (here N corresponds to 8) then working from left to right, top to bottom the DCT is applied to each block. Each block‘s elements are compressed through

Quantization means dividing by some specific 8X8 matrix. To reconstruct the image, receiver decodes the quantized DCT coefficients and computes the inverse two dimensional DCT (IDCT) of each block, then puts the blocks back together into a single image in same manner as we done in previously. The dequantization is achieved by multiplying each element of the received data by corresponding element in the quantization matrix Qmatrix, then 128 added to each element for getting level shift. In this decoding process, we have to keep block size (8X8) value same as it used in encoding process. The input image is the same taken in the previous algorithm. The steps of compression are shown in the above diagram. Wavelet transform converts the image into high frequency and low frequency bands also known as low pass and high pass decomposition and reconstruction filters. The decomposition filters are applied to obtain the DWT transformed image and then based on a compression threshold value the DWT coefficients are compressed. The compressed DWT domain values are converted back to the spatial domain by using the reconstruction filters. This gives the resultant compressed image.

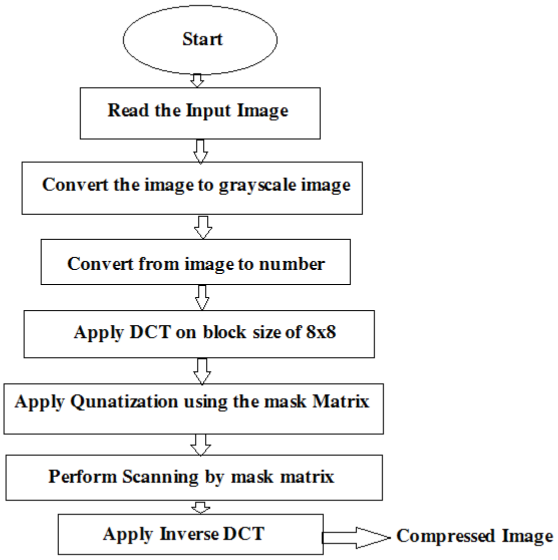



**Fig 13:** Steps for DCT Algorithm

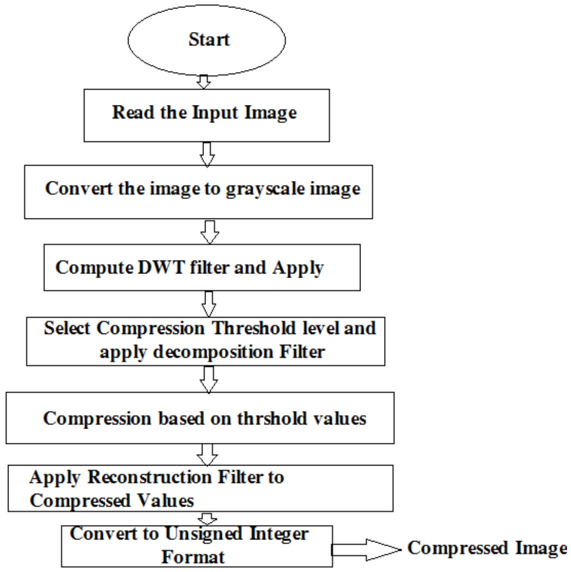



**Fig 14:** DWT Compression Algorithm

**Algorithm**

1. Input image is read into the system.
2. Conversion to grayscale is performed.
3. 2-D wavelet filler bank at a given level n, the detail coefficients are output, while the whole filter bank is applied again upon the approximation image until the desired maximum resolution is achieved.
   - LLn represents the approximation image nth level of decomposition, resulting from low-pass filtering in the vertical and horizontal both directions.
   - LHn represents the horizontal details at nth level of decomposition and obtained from horizontal low-pass filtering and vertical high-pass filtering.
   - HLn represents the extracted vertical details/edges, at nth level of decomposition and obtained from vertical low-pass filtering and horizontal high-pass filtering.
   - HHn represents the diagonal details at nth level of decomposition and obtained from high-pass filtering in both directions.
4. Threshold level is selected. All pixels below this threshold are removed resulting in less pixels and compression.
5. The compressed DWT coefficients are then converted into unsigned integer format using reconstruction filter i.e. for the image. This represents the compressed final image

**Results**

The images taken for the implementation and testing in this thesis are of '.png' type and of pixel size 256 x 256 width into height.
Image Name: Baboon.png
Size on Disk: 86 kb
After DCT Compression: 7.76 kb

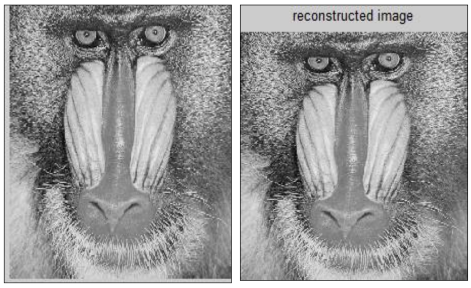



**Fig 15:** a) Input Image and b)Compressed Image

Image 2: Peppers.png
Size of Original Image: 79.9 kb
DCT Compression: 7.03 kb

(a) (b)

**Fig16:** a) Peppers (Input) (b) DCT Compressed

Image 3: Barbara
Size of Original Image: 85.6 kbDCT Compression: 7.03 kb

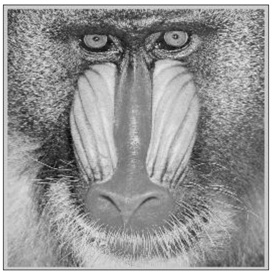
(a) (b)

**Fig 17:** a) Barbara (input) b) DCT Compressed Image

Image 4: Lena

**Fig 18:** Lena (input) **Fig 19:** b) DCT Compressed Lena

Size on disk: 180 kb
DCT Compressed: 6.50 kb
Image 1: babbon.png
Size on Disk: 83.3 kb
DWT Compressed: 21.2 kb



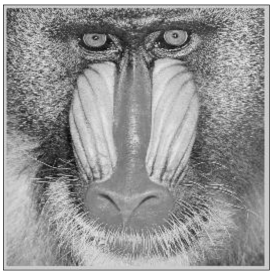
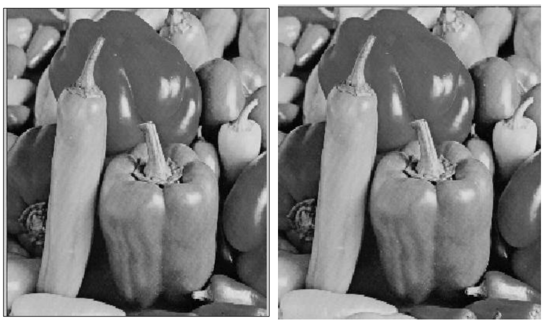


**Fig 20:** Baboon Image **Fig 21 (b):** DWT Compressed

Image 2: peppers.png
Size on Disk:
DWT Compressed: 11.9 kb



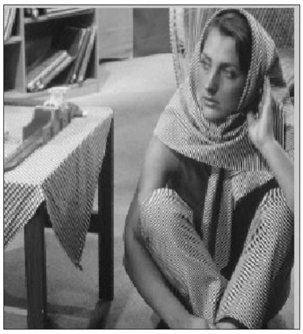
**(a)** **(b)**

**Fig 22:** a) Peppers (Input) b) DWT Compressed

Image 3: Lena
Size on Disk:
DWT Compressed: 11.1 kb

**Fig 23:** a) Lena (input) **Fig 24:** b) DWT Compressed

Image 4: Barbara
Size on Disk: 85.6 kb
DWT Compressed: 14.9 kb



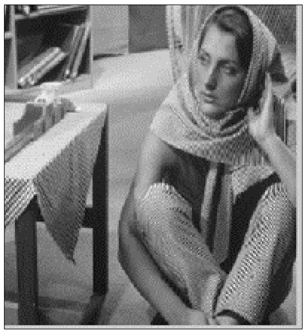


**Fig 25:** a) Barbara (input), **Fig 26 b):** Barbara Compressed DWT

**Table 2:** Comparative Analysis of DCT and DWT Techniques

| Image | Size on Disk | Compressed Size DCT | Compressed Size DWT |
|---|---|---|---|
| Baboon | 86 Kb | 7.76 Kb | 21.8 Kb |
| Peppers | 79.9 Kb | 7.03 Kb | 12.4 Kb |
| Barbara | 85.6 Kb | 7.13 Kb | 15.4 Kb |
| Lena | 70.1 Kb | 6.52 Kb | 12.0 Kb |

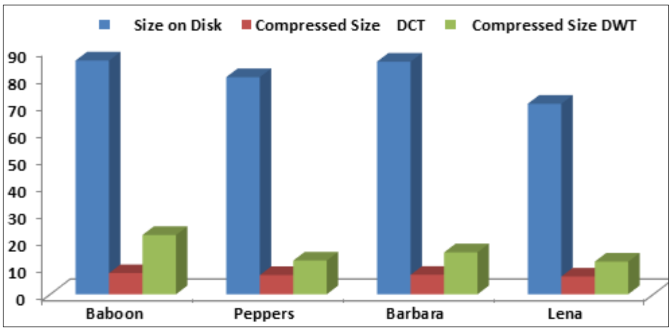



**Fig 26:** Comparative Analysis of DCT and DWT Techniques

**Table 3:** Comparison Ratio

| Image | Compression Ratio DCT | Compression ratio DWT |
|---|---|---|
| Baboon | 11.08 | 3.944 |
| Peppers | 11.36 | 6.44 |
| Barbara | 11.72 | 5.59 |
| Lena | 10.75 | 5.84 |

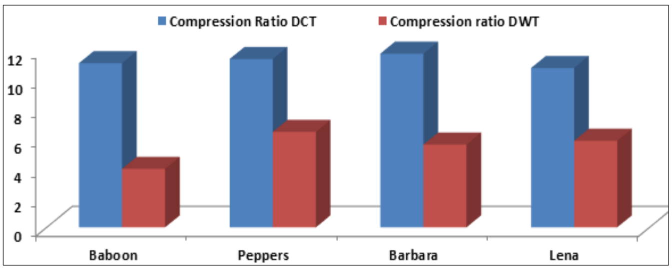



**Fig 27:** Comparison Ratio

**Conclusion**

Image compression is very important for efficient transmission and storage of images. The work in this thesis, primarily focused at comparing the two most widely used techniques in the image compression domain i.e the Discrete Wavelet transform, and the Discrete Cosine Transform on a number of images. The techniques have been applied successfully and the results of compression using both the techniques have been compiled. The implementation has been carried using the MATLAB software and a number of images from the standard database. The DCT technique uses 8x8 blocks conversion. The comparison shows as given in the results chapter that for the same input image the compression in DCT technique is more than the DWT technique. However, the quality of the image decreases. There always lies a tradeoff between the compression ratio and perceptual quality of the image obtained and it largely depends on the usage to decide the priority of which method to choose over the other. If the focus and usage is entirely on compression and image quality is a less important factor, then the preferred method should be DCT as described in this thesis. However, if the quality of image is also to be maintained while compressing into smaller disk size, then the DWT based compression technique must be employed.

**Future Work**

This research work gives a comparison between two widely used image compression techniques. The future research may include a hybrid technique which eliminates the disadvantages of both the techniques and will obtain better compression while maintaining the perceptible quality of the image. The usage of artificial intelligence and fuzzy logic techniques can also be envisaged for reducing the redundant pixels in the image and obtaining better compression ratio.

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