Int. J. Adv. Multidiscip. Res. (2025). 12(11): 35-41

International Journal of Advanced Multidisciplinary Research
ISSN: 2393-8870
www.ijarm.com
(A Peer Reviewed, Referred, Indexed and Open Access Journal)
DOI: 10.22192/ijamr Volume 12, Issue 11-2025

Research Article

DOI: http://dx.doi.org/10.22192/ijamr.2025.12.11.003

An Overview of Digital Image Compression Techniques

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Keywords

Image Compression,
GIF,
JPEG,
TIFF,
PNG,
BMP

Abstract

Image Compression is one of the sub extensions of Digital Image Processing. Image Compression is underestimating the length in bytes of an image file without compromising the features of the image representation. The file length decline arrangement admits more representations expected to be stored in a likely amount of disc or thought space. It again minimizes the moment of truth necessary for countenances expected to be shipped over the Internet. There are many habits at which point concept files may be compacted. The JPEG layout and the GIF layout are the two common compressed image formats for web application. The JPEG pattern is often used for photographs, while the GIF design is used for line creativity and added concepts accompanying line shapes that are completely natural. The aim of Image compression research reduces the number of parts needed to show a countenance by killing the geographical and ghostly redundancies.

1. Introduction

A. Digital Image Fundamentals

An image is a 2D function f, f(x, y), where x and y are coordinate points, and the size of 'f' at any pair of relates (x, y) is named the force level of the figure at another position point.

A digital image is a group of established elements, each of that has a distinguishing position and profit. These components are referring to as pixels.

Image as a Matrix

Images are represented in rows and columns. The following syntax can be used to represent an image:

$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1) & f(0,2) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & f(1,2) & \dots & f(1,N-1) \\ . & . & . & & . \\ . & . & . & & . \\ . & . & . & & . \\ f(M-1,0) & f(M-1,1) & f(M-1,2) & \dots & f(M-1,N-1) \end{bmatrix}$$

Using the above format, the right side of this equation is a mathematical representation. Every point of the above matrix is named a figure item, picture factor, or pixel.

B. Types of Images

i) Binary Images

The Binary Images are the elementary type of figures, which are generally second-hand for comprehensive shape or outline. It uses only two principles that are Black (0) and White (1). It consists of a single-bit image and likewise it takes only 1 binary digit to show a pixel.

Example: Optical Character Recognition (OCR).

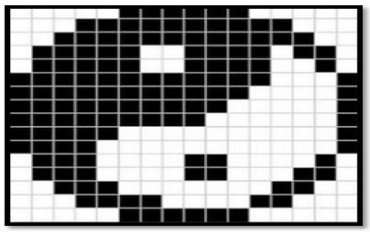

Fig. 1: Binary Image

ii) Grey-scale Images

Grey-scale Image is monochrome pictures. They have just one colour. Grey-scale pictures do not contain any data about colour shading.

An ordinary grey-scale image contains 8 bits of/pixel information, which has 256 distinctive grey levels. In clinical data pictures 12 or 16 bits/pixel pictures are utilized.

Fig. 2: Grey-scale Image

iii) Colour Images

Colour Images are three bands fixed pictures at which point, each band holds an alternate colour and the evident dossier is stocked in the mathematical concept.

The pictures are tried as red, green and blue (RGB pictures). Each colour picture has 24 bits/pel means 8 bits for each individual of the three colour band (RGB).

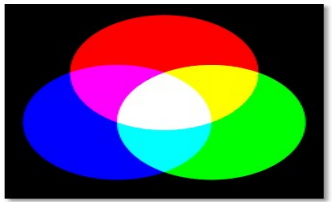

Fig. 3: Colour Image

C. Image File Formats

Image File Formats are normalized form for systematizing and packing mathematical figures.
A picture file plan ability store image data in an uncompressed layout, a compressed layout, or a vector plan. The most frequently image file representation layouts are:

i) Tagged Image File Format (TIFF)

TIFF concepts create intensely massive file sizes. TIFF concepts create intensely massive file sizes. TIFFs are furthermore very responsive in conditions of colour (they may be CMYK for print or gray **scale** or RGB for netting) and content (figure tags, coatings). TIFF is the most widely used file type used in Photo Software (like Photoshop), while page design operating systems, and repeatedly cause a TIFF to hold a gigantic number of representation files.

ii) Joint Photographic Experts Group (JPEG)

JPEG files are representations that have been compressed to store tremendous amounts of data in a limited content file. JPEG files are repeatedly used for photographs on a computer network, causes they produce a limited file that is to say absolutely intoxicated on a location on the WWW and further looks good.

iii) Graphics Interchange Format (GIF)

GIF is most suitable for storing graphics with few of the colours that contain plain drawings, shapes, trademarks, and sketch style figures. GIF files are occasionally tinier in size and are handy. GIF file can also be used for animations.

iv) Portable Network Graphics (PNG)

PNG is used completely for netting concepts, not for publication representations [3]. For photographs, PNG is not as most as JPEG, because it creates a hug file. In the images with some text, or line art, it's better, because the images look less "bitmappy."

v) Bitmap (BMP)

The BMP file method is used in Graphic files in the Microsoft Windows OS. In general, Bitmap files are uncompressed, and from now on abundant and lossless; the disadvantages are plain construction and expansive acknowledgment in Windows programs.

vi) Raw Image Files (.raw)

Raw Image Files are crude and constructed by a camera or scanner. These images are the corresponding of mathematical negative, signification that they hold a plenty of information. These representations need to be treated in the way that Adobe Photoshop or Light Room. It saves metadata and is used for photography**.**

2. Literature review

K. Ranjeet et al. [4] presented a research overview of image compression, techniques with its future scenario. Image storage is necessary for several purposes like medical images, Magnetic Resonance Imaging (MRI) and radiology. Picture is needed for satellite images, documents. Picture compression is essential for some type of techniques [6]. Some popular image compression techniques were described in this paper [5]. Nitu

Rani et al. [8] analysed comparative act of DCT & DWT transforms based on a variety of parameters. The main reason of image compression is to decrease the redundancy and irrelevancy there in the image, so that it can be stored and transferred proficiently [7].

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3. Methodology

I. Image Compression Process

Fig. 4 illustrates an image compression framework consisting of two distinct functional components: an encoder and a decoder. The encoder is responsible for the compression, while the decoder carries out the reverse function of decompression.

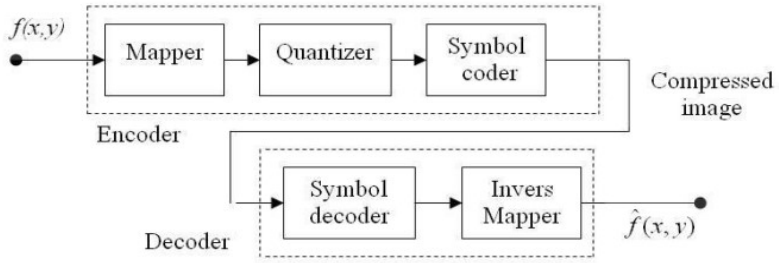

Fig. 4: Block Diagram of an Image Compression System

The input image f(x, y) is processed by the encoder, which generates a compressed version of the original input. When this compressed representation is fed into its corresponding decoder, a reconstructed output image f(x, y) is produced. In general, f(x, y) may or may not be an exact replica of f(x, y). If it is, the compression system is termed error-free, lossless, or data-preserving. If it isn't, then the reconstructed output image is distorted, and the compression system is referred to as lossy.

II. Types of image compression

There are two categories of image compression. They are:

A. Lossy Compression
B. Lossless Compression

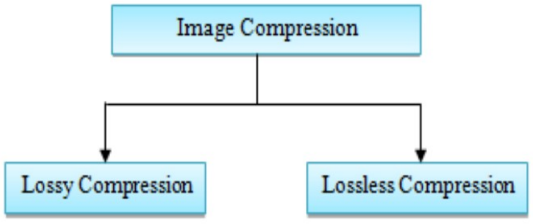

Fig. 5: Types of Image Compression

A. Lossy Compression

Lossy Compression techniques, involve a few losses of information, and data cannot be retrieved from them. These techniques are used when a certain amount of data loss is acceptable. Typically, multimedia data is compressed using this method. As of now, JPEG is the most suitable method for lossy compression.
Some of the Lossy Compression Techniques are:

i) Predictive Coding

This method provides effective compression with minimal additional burden. It relies on removing the redundancies between closely located pixels by only encoding the new information in each pixel. The predictive coding system includes an encoder and a decoder, both equipped with the same predictor. The predictor converts a collection of high-entropy yet correlated values into a series of low-entropy but less correlated values.

ii) Transform Coding

Transform Coding is utilized to change spatial pixel values of an image into transform coefficient values. Given that this is a linear operation and there is no loss of data, the total number of coefficients generated matches the number of transformed pixels. The Discrete Cosine Transform (DCT) is the most commonly utilized method for lossy compression. This method is a variant of the Fourier transform and was initially introduced by Nasir Ahmed, T. Natarajan, and K. R. Rao in 1974. In discussions about a group of discrete cosine transforms, the DCT is often referred to as "DCT-II." It typically serves as the organized method for compressing images. DCT is used in JPEG, which is the most recognized lossy format, as well as in the newer HEIF.

iii) Fractal Image Compression

Fractal Image Compression is a lossy method for reducing the size of digital images that relies on fractals. This method is most effective for natural images and textures, based on the principle that different sections of an image commonly resemble other sections within the same image.

Fractal algorithms transform these sections into m athematical representations known as "fractal cod es," which are utilized to recreate the encoded ima ge.

iv) JPEG

The JPEG format is one of the most commonly used formats for saving photographs and images.

The word "JPEG" stands for

Joint Photographic Experts Group, which created the standard in 1992. JPEG is based on the Discrete Cosine Transform (DCT), which is a lossy method for compressing images. JPEG was fundamentally responsible for the creation of digital images and photographs online and subsequently on social media.

JPEG compression utilized for various image file formats. JPEG is the most commonly used image format by digital cameras and other devices that capture photographic images; in conjunction with JPEG/JFIF, it is the most prevalent format for saving and sharing photographic images on th e internet. These design variations are often not di fferentiated and are merely referred to as JPEG.

B. Lossless Compression

Lossless Compression allows the actual data to be retrieved accurately from compressed data. Due to the fact that it utilizes all the information in the image, the decompressed image will be exactly the same as the original. Geometric shapes are quite simple, and can be considered lossless image compression. There are several well-known lossless compression formats, including GIF, Zip, and TIFF.

Some lossless image compression techniques are:

i) Run Length Encoding (RLE)

RLE is a simple technique that replaces sequences of identical data values (runs) with a single value and a count of its occurrences. For example, "AAAAABBC" would become "5A2B1C".

It is particularly effective for images with large areas of uniform color, such as line drawings or simple graphics.

ii) Huffman Coding

This is a variable-length coding technique that assigns shorter codes to frequently occurring symbols (pixel values or differences) and longer codes to less frequent ones.

It constructs a binary tree based on symbol frequencies to generate optimal prefix codes, ensuring no code is a prefix of another, which prevents ambiguity during decoding.

iii) Lempel-Ziv-Welch (LZW) Compression

LZW is a dictionary-based compression algorithm that identifies and replaces repeating sequences of data with shorter codes that refer to entries in a dynamically built dictionary.

It is used in formats like GIF and TIFF (optionally), and was the basis for the Unix compress utility.

iv) PNG (Portable Network Graphics) Compression

PNG utilizes a two-step lossless compression process: Filtering: It analyses rows of pixels and predicts pixel values based on neighbouring pixels, storing the differences rather than the raw pixel values. This aims to create smaller differences, leading to better compression.

III. Benefits and drawbacks of image compression

Benefits:

i) Reduced File Sizes

Less demanding record sizes also simplify the use of images in photo editing software. The simpler the image, the less RAM and CPU time it requires to process.

ii) Faster Transfers

Compressed images are frequently used on the Int ernet, where speed is prioritized over quality.

Drawbacks:

i) Reduction in Quality

The reduction in file size when image compressio n is utilized comes with notable drawbacks, prima rily a decline in the overall quality of the image

ii) Variable Standards

This allows us the flexibility to choose the ideal size/quality ratio for our essentials.

4. Experimental findings

The suggested work in this paper evaluates how well different image compression methods perform. In this work, the algorithms have been implemented in Python. This proposed research study uses a variety of image types including medical and natural images. Because it is difficult to obtain images with a crude structure the currently packed data image in JPEG design is taken into consideration for analysis.

Fig. 6: Original Image before Compression

Fig. 7: Decompressed Image after Compression

5. Conclusion

To balance storage requirements with acceptable visual quality digital image compression is crucial for effective data transmission and storage. Reducing redundant and unnecessary information in an image is the fundamental idea behind lowering its file size. Two primary methods are used to accomplish this: lossy compression which attains higher compression ratios by removing less noticeable details making it appropriate for consumer applications but not for high-precision images and lossless compression which precisely recreates the original image but provides only modest gains. Techniques like Run-Length Encoding (RLE) and Discrete Cosine Transform (DCT) which are used in JPEG are typical examples of lossy and lossless methods respectively. The exact applications requirements will determine which approach is best.

This paper has explained the different types of images, image file formats, type of image compression, general image compression system, various image compression techniques and the advantages and disadvantages of image compression.

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How to cite this article:
T. Sujatha. (2025). An Overview of Digital Image Compression Techniques. Int. J. Adv. Multidiscip. Res. 12(11): 35-41.
DOI: http://dx.doi.org/10.22192/ijamr.2025.12.11.003

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Quick Response Code	Website: www.ijarm.com
	Subject: Computer Science
DOI:10.22192/ijamr.2025.12.11.003	