European Journal of Research Development and Sustainability (EJRDS)
Available Online at: https://www.scholarzest.com
Vol. 4 No 03, March 2023
ISSN: 2660-5570

DIGITAL IMAGE COMPRESSION APPROACHES: A CASE STUDY

Firas S. Abdulameer
Department of physics, College of Science, Mustansiriyah
University, Baghdad, Iraq
Email: firasalaraji@uomustansiriyah.edu.iq

Article history:
Received: 1st January 2023
Accepted: 1st February 2023
Published: 6th March 2023

Abstract:
Digital images require a vast number of bits to represent them, and their canonical representation typically contains a substantial degree of redundancy. By taking advantage of these redundancies, image compression algorithms lower the number of bits necessary to represent an image. In order to overcome this redundancy, this paper discusses several image compression approaches and their advantages.

Keywords: Digital images; Visual Quality; Case Study; Compression Approaches

1. INTRODUCTION

1.1 Digital Image

Pixels are the building blocks of digital images, and each pixel indicates the color existing at a specific location within the image. We are able to generate a digital representation of an image by taking readings of its color at a significant number of points across the image. In arrays, the pixels are laid out in a grid consisting of rows and columns in a predetermined arrangement. A quantitative representation of a two-dimensional image is what we refer to as a digital image [1].

1.2 Compression of Images and its Use

The goal of image compression is to bring the reconstructed image's resolution and visual quality as close to the original image as possible, while at the same time minimizing the amount of redundant data contained within the image data. This makes it possible to store or transmit the data using as little space or bandwidth as is practically possible [1].

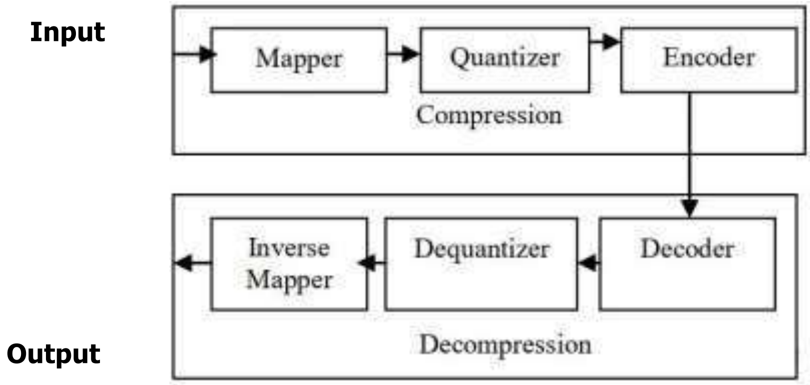

Figure 1. Compression and Decompression

The primary goal in the process of data compression is to reduce the volume of image data (in terms of bits) while maintaining the integrity of the information. Image data compression is a key component of digital camera design and digital photography. As illustrated in figure 1, the mapper first converts the image it is given into a format intended to cut down on the amount of inter-pixel redundancy. The second stage, known as the quantizer block, is responsible for reducing the precision of the mapper's output in line with a set of parameters established in advance. In the third and last stage of the process, a symbol decoder generates a code for the quantizer output and then maps the production following the code. In the opposite sequence, these blocks carry out the activities that the encoder's symbol coder and mapper block typically carry out. When one calculates the number of bits per image produced due to conventional sampling rates, the requirement for image compression becomes readily evident. Take, as an illustration, the necessary quantity of storage space and bandwidth for the transmission of photos, which is depicted in figure 2. A low-resolution video image with 512 by 512 pixels, 8 bits per pixel, and three colors would need 6106 bits to be transmitted over telephone lines using a modem operating at 9600 baud (bits per second). This would take around 11 minutes for just one image [1,2,3].

Figure 2. Digital Image

1.3 Why can we compress?

1. Spatial Redundancy: Pixels in close proximity are not independent; they are linked. So that redundant data inside a single frame can be eliminated.
2. Temporal Redundancy: Reduces the number of bits required to represent an image or its data.
3. Spectral Duplicity: This is because of the relationship between several color planes.

2. COMPRESSION BENEFITS

1. The reduced file size that is produced as a result of compression requires significantly less space to save on your hard disk, website, or digital camera. Additionally, it will make it possible to record a greater number of photographs onto other media, such as a photo CD. It is also feasible to view more photographs in a shorter amount of time because to the fact that compressed images load faster than their more laborious original counterparts [4].
2. On the internet, photographs that have been compressed not only cut down the amount of time it takes to upload and download a web page. In terms of both space and bandwidth, they require less of the server's resources to store and process. So that the total amount of time it takes to execute can be reduced.
3. Because fewer bits are transmitted, it lowers the likelihood that there will be an error during the transmission.
4. It also offers some protection against unauthorized monitoring in some situations.

3. TECHNIQUES OF IMAGE COMPRESSION

There are numerous different methods for compressing images; nevertheless, these methods may be broken down into two primary categories [5 and 6].

1. Lossless Techniques
2. Lossy Techniques

3.1 Lossless Techniques

Techniques for lossless picture compression allow the original data to be reconstructed from the compressed data after the technique has been applied. When it is vitally critical that the original data and the data that has been decompressed be exactly the same, lossless compression is the method of choice. The compression ratio is not that high. Examples are executable programs, written documents, and source code. PNG and GIF are two examples of picture file formats that use lossless compression exclusively [7]. The following compression methods are covered in lossless compression (Figure 3):

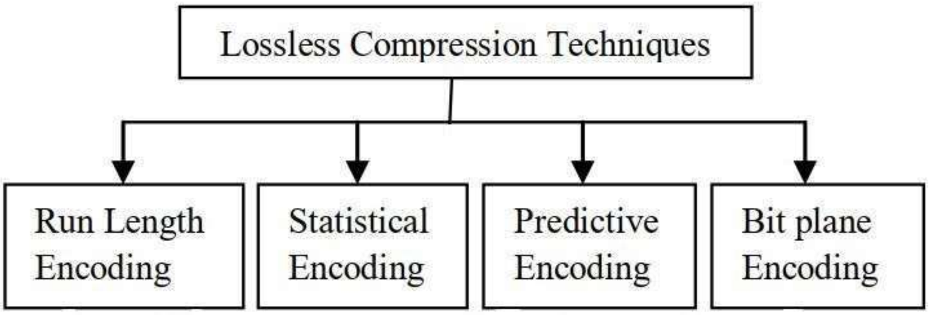

Figure 3: The Lossless Compression Techniques

1- Encoding of the Run Length

The run-length encoding technique is perhaps the least complicated compression approach. When dealing with data that is repetitious, it is an extremely helpful tool. Using this method, longer sequences of identical symbols (pixels), known as runs, are exchanged for shorter symbol sequences. The fundamental principle underlying this approach is to replace each instance of a symbol that occurs consecutively and repeatedly with a single instance of the symbol, which is then followed by the total number of occurrences [8, 9].

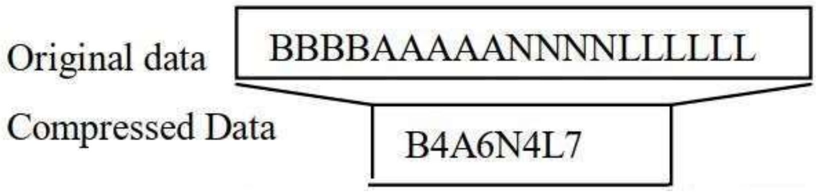

Figure 4: Overview of the run length encoding

2- Encoding Using LZW

Lempel Ziv Dictionary-based encoding is a category of algorithms, and
Welch encoding is one example of this type of encoding. The goal is to compile all of the strings that were exchanged throughout the communication session into a dictionary, which will take the form of a table. If the sender and the receiver both have a copy of the dictionary, then it will be possible to decrease the quantity of information that is sent by replacing strings that have been encountered in the past with their respective indexes in the dictionary.

3- Encoding Predictive of Data

A method of statistical estimation in which unknown random variables in the future are estimated or forecasted based on known random variables in the past and in the present. The most popular kind of lossless predictive coding is known as lossless differential pulse code modulation (DPCM), which stands for "lossless pulse code modulation." To generate a predicted image using the lossless DPCM scheme, the value of each pixel in the original image, with the exception of those at the image's boundaries, is first predicted based on the images of its neighbors. After that, the image known as the differential or residual image is obtained by computing the difference between the actual pixel values and the predicted pixel values. The dynamic range of the pixel values in the leftover image will be significantly reduced. After that, the image is encoded in an effective manner using Huffman coding.

4- Arithmetic Coding

Unlike Huffman coding, arithmetic coding does not compress each symbol using a discrete number of bits. the full data \sequence is coded with a single code. Consequently, the correlation between adjacent pixels is exploited. The significant setback the arithmetic coding is its low speed since of several essential and divisions for each symbol. The essential concept of arithmetic coding is to assign an interval to each symbol. Beginning with the interval [0...1], each interval is subdivided into subintervals whose sizes are proportional to the current probability of the respective alphabetic characters.

5- Encoding Done on a Bit Plane

In most cases, the pixels that are adjacent to one another are connected. This indicates that the values of the nearby pixels are slightly different from one another. They can be captured by the representation of pixel values in gray code in such a way that the values of neighboring bits in the bit planes have values that are comparable to one another. This results in the individual bit planes being created. After that, each of the bit planes can be efficiently programmed using a method that does not incur any data loss. Decomposing a multilayer image into a sequence of binary images and then compressing each binary image is the foundation on which this method is built.

3.2. Lossy Techniques

The process of lossy compression operates somewhat differently. These tools do little more than strip the file of "unnecessary" information, reducing its overall size and making it more manageable. This method of compression is frequently utilized in lowering the file size of bitmap photographs, which have the propensity to be significant. This may examine the color data for a variety of pixels and identify minute variations in the value of the pixel's color that are undetectable to the human eye and brain due to their similarity. These variations are so minute that they cannot be distinguished. The algorithm may select a more limited range of pixels whose changes in color value fall inside the bounds of our perception, and then it will substitute those pixels for the others. A framework for lossy compression is illustrated in figure 5.

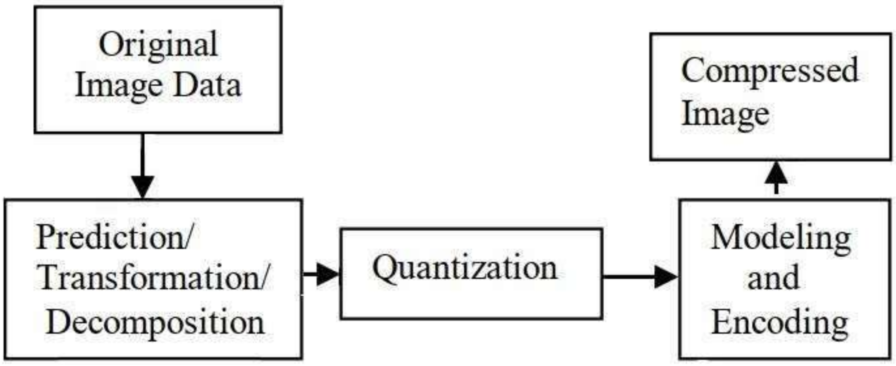

Figure 5: Lossy Compression Framework

In order to reach this objective, one of the procedures listed below must be carried out; 1. The predicted image is created by estimating the values of individual pixels in the original image based on the values of their nearby pixels. After that, the difference between the anticipated and original images is known as the residual image; 2. Transformation is a procedure that can be reversed and either eliminates duplication or creates an image representation more conducive to effectively extracting and coding pertinent information; 3. Quantization procedure reduces a range of values to a single quantum value.

When the total amount of discrete symbols in a stream is cut down, the stream as a whole can be compressed further. After that, entropy coding is utilized to accomplish more compression. The compression ratio (CR), the signal-to-noise ratio (SNR) of the reconstructed image compared to the original, and the speed at which the image may be encoded and decoded are three essential factors to consider when evaluating the performance of a lossy compression method [9,10].

1- Coding Transformations

The first step in most transform coding algorithms is to partition the original image into several smaller images called blocks. These blocks are typically 8 by 8 pixels in size. Calculating the transform coefficients for each block effectively converts the initial 8 x 8 array of pixel values into a collection of coefficients. The coefficients closer to the top-left corner of the array typically contain most of the information required to quantize and encode the image with relatively little perceptual distortion. After this, the resulting coefficients are subjected to quantization, and a symbol encoding technique employs the output of the quantization process to generate the output bit stream that represents the encoded image.

2- Coding of the Sub-Bands

Quantization and coding are applied to each band after the image is analyzed to produce the components containing frequencies in well-defined bands, referred to as the sub-bands. The primary idea that underpins Sub-band Coding, also known as SBC, is that the image is broken up into these sub-bands. The optimal quantization and coding design for each sub-band may be accomplished independently using this system, which is one of its many benefits [10].

3- Truncation Coding Block

Block Truncation Coding is a lossy image compression techniques. It is a straightforward method that requires a reduced amount of processing complexity. BTC is a relatively new method for compressing the data associated with black-and-white images. The picture is broken up into individual sections of pixels that do not overlap one another. The threshold and reconstruction values are figured out for each block individually. In most cases, the threshold is calculated as the average value of each pixel in the block. After that, a bitmap of the block is created by setting all pixels whose values are higher than or equal (lower than) the threshold to a value of 1 and then making the bitmap (0). After that, the reconstruction value is figured out for each bitmap section individually. The importance of the pixels corresponding to each other in the original block has been averaged to produce this result.

4- Quantification Based on Vectors

It offers a high compression ratio while simultaneously simplifying the decoding procedure. The method in question is known as the development of a dictionary of code vectors, which are vectors of a fixed size. After that, a picture is divided into sections that do not overlap and are referred to as image vectors. Then, the vector in the dictionary that provides the closest match is identified for each image vector. The index at which that vector appears in the dictionary is used to encode the first image vector. VQ-based coding schemes are particularly appealing to the development of multimedia applications due to their rapid lookup capabilities on the decoder side of the equation.

5- The Process of Fractal Coding

The method works best with natural images and textures. It relies on the fact that different parts of an image frequently resemble other parts of the same idea. These similarities are converted into mathematical data known as "fractal codes," which are then used to recreate the encoded image. The method is most effective when applied to natural images and textures. After an image has been transformed into fractal code, the relationship between the image and a particular resolution is severed, resulting in an image that is resolution independent. The image can be reproduced to fill any screen size without introducing image artifacts or loss of clarity in pixel-based compression systems. This is possible because the image is not being compressed into individual pixels.

6- Encoding Predictive Messages

The difference between the lossy and lossless versions of lossy DPCM (Differential Pulse Code Modulation) is minimal. The most crucial distinction is that in lossy DPCM, the values of individual pixels are predicted rather than "reconstructed" based on the importance of nearby pixels. The differential picture, also known as the residual image, is the image that is created by subtracting the anticipated value from the actual value of each pixel. It has a significantly lower correlation than the initial image.

4. CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

The widespread use of digital photographs is anticipated to proceed at an ever-quicker rate in the years to come. Both the storage capacities and the transmission bandwidths are being stretched to their limits due to the massive size requirements of images and the explosive increases. Compression is an effective strategy for overcoming obstacles like this. Compression methods can be split into two categories in their most basic forms. The first technique is known as lossless compression, and the second is known as the lossy compression technique. The criteria that are used to determine which algorithm is the best are as follows:

1. The high-definition nature of the picture.
2. The degree to which there is compression
3. The rate at which compression occurs.

The strategies that have been developed for data compression have much room for development in the future. The prediction can be enhanced even more in a lossless scheme by employing the Neuro-Fuzzy technique, which will result in a further reduction in the prediction error. Utilizing an adaptive reversible approach is one way in which the image quality and the compression ratio can be increased further. The majority of the methods have excessive computational complexity, which can be further reduced.

REFERENCE

1. D. He, Y. Zheng, B. Sun, Y. Wang, and H. Qin, "Checkerboard context model for efficient learned image compression," in Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, 2021, pp. 14771-14780.
2. Doaa Mohammed, Fatma Abou-Chadi. "Image Compression using Block Truncation Coding". JSAT February edition 2011.
3. David H. Kil and Fances Bongjoo Shin, " Reduced Dimension Image Compression And its applications,"Image Processing, 1995, Proceedings, International Conference,Vol. 3 , Oct.,1995.
4. Sindhu M, Raj Kamal R , " Images and Its Compression
5. Techniques" , International Journal of Recent Trends in Engineering , Vol 2,No.4, November 2009.
6. X. Jia, X. Wei, X. Cao, and H. Foroosh, "Comdefend: An efficient image compression model to defend adversarial examples," in Proceedings of the IEEE/CVF conference on computer vision and pattern recognition, 2019, pp. 6084-6092.
7. J. Ballé, V. Laparra, and E. P. Simoncelli, "End-to-end optimized image compression," arXiv preprint arXiv:1611.01704, 2016.
8. F. Mentzer, E. Agustsson, M. Tschannen, R. Timofte, and L. V. Gool, "Practical full resolution learned lossless image compression," in Proceedings of the IEEE/CVF conference on computer vision and pattern recognition, 2019, pp. 10629-10638.
9. N. Johnston et al., "Improved lossy image compression with priming and spatially adaptive bit rates for recurrent networks," in Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, 2018, pp. 4385-4393.
10. M. Yang and N. Bourbakis, "An overview of lossless digital image compression techniques," in 48th Midwest Symposium on Circuits and Systems, 2005., 2005, pp. 1099-1102: IEEE.
11. M. A. Rahman and M. Hamada, "Lossless image compression techniques: A state-of-the-art survey," Symmetry, vol. 11, no. 10, p. 1274, 2019.