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Review on techniques and file formats of image compression

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ABSTRACT

This paper presents a review of the compression technique in digital image processing. As well as a brief description of the main technologies and traditional format that commonly used in image compression. It can be defined as image compression a set of techniques that are applied to the images to store or transfer them in an effective way. In addition, this paper presents formats that use to reduce redundant information in an image, unnecessary pixels and non-visual redundancy. The conclusion of this paper The results for this paper concludes that image compression is a critical issue in digital image processing because it allows us to store or transmit image data efficiently.

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1. INTRODUCTION

Image compression is a technique that is applied to images to store or transmit them efficiently. It uses digital data compression techniques [1-4], it is the process of reducing the size of data to represent a certain amount of information. That is, a data set can contain redundant data that is of little relevance or is data that is repeated in the collection, which, if identified and can be deleted [3]. In images domain, several forms of image representation are identified, according to the style used, at least three types are applied to reduce the number of redundant data, eliminate redundant code, eliminate unnecessary pixels and eliminate visual redundancy. The objective to eliminate redundant code is to use the smallest number of symbols to represent the image; in this type, it is usual to use Huffman coding compression and arithmetic coding techniques, which use statistical calculations to eliminate this type of redundancy and reduce the original data occupancy [1-4].

In the case of eliminating redundant pixels, most images have similarities or correlations between pixels due to similar structures in the images. In this way, the value of a pixel can be used to predict that of its neighbors' techniques such as Lempel-Ziv are used to eliminate this redundancy. The vision human eye (VHS) responds with different sensitivity to the visual information it receives. The information to which it is less sensitive can be discarded without affecting the perception of the image, suppressing what is known as visual redundancy, and producing at the same time the loss of specific characteristics of the image. The elimination of redundancy is related to the quantification of information, which is a process that leads to irreversible damage to information. Compression formats such as JPEG and TIFF allow techniques with information loss.

In general, image compression techniques can be grouped into two main classes, lossless compression, and lossy compression. In some images, not it is permissible to lose information in the compression process, such as medical or legal images. While in other images, it is possible to allow some degree of error, while maintaining image quality, to optimize image compression, for example in video conferencing images. Likewise, it is important to mention that compression techniques are not always used separately; on the contrary, lossy compression techniques use lossless compression techniques to achieve better compression. This paper will be made a brief description of the main techniques and formats of image compression [5-7].

2. CODING OF IMAGES

An image can be defined as a two-dimensional function of light intensity $f(x, y)$, where x and y represent the spatial coordinates and the value of f at any point (x, y) is proportional to the brightness or grey level (scale grey) of the image at that point. A digital image is an image $f(x, y)$ that has been discretized in both spatial coordinates and brightness; and can be considered as an array whose row and column indexes identify a point in the image and the value of the corresponding element of the matrix indicates the level of grey at that point. The elements of the digital distribution of this type are called elements of the image or pixels [1-4].

The images we perceive are composed of radiations of different lengths of electromagnetic waves. Each range is associated with a color. The vision parameters are luminance, dye, and saturation. Any color is obtained by a weighted sum of the basic colors: red, green, and blue, including gray levels. Color spaces can be defined as the different mathematical bases that can be useful to represent luminous information. The best known is the RGB space, in which the primary colors red, green, and blue are represented; see representation in Figure 1. The disadvantage of this space is that it presents redundancy of information between the three colors; to save this (1), (2), (3), it is possible to convert to another color space, for example, to the YUV. The formulas for conversion are:

$$Y=0.3R+0.6G+0.1B \text{ (Brightness or luminance level) [3]} \quad (1)$$

$$U=B-Y \text{ (blue color difference, Cb) [3]} \quad (2)$$

$$V=R-Y \text{ (red color difference, Cr) [3]} \quad (3)$$

where: U and V are known as chrominance or color information.

Some characteristics about human perception that can be highlighted are: the eye is more sensitive to some colors than others, for example, given three sources of light with the same intensity and different color (one red, one green, and one blue), the eye perceives green with twice the intensity of red, and six times more intense than blue. Likewise, human visual perception mechanisms are less sensitive and strict than auditory ones, for example, in frequency variations, image suppression [8-11].

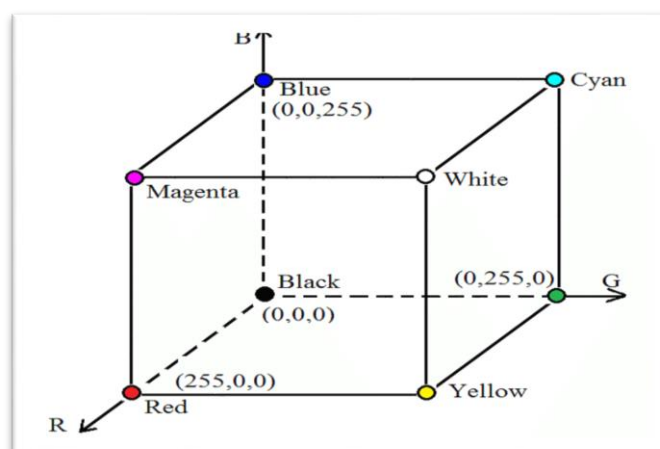


Figure 1. RGB system (red, green, blue)

Otherwise, each RGB sample is encoded with a number of bits per color component, for example, 8 bits per component use 24 bits per sample. The resolution of an image is measured according to the number of pixels per side (width x height). In digital cameras, it is usually measured in Megapixels; that is, millions of pixels per image. The CIF format (Common Intermediate Format) contains 352x288 pixels, traditionally used in videoconferencing; the VGA (640x480) used by low-quality cameras; n-Megapixels offered by higher quality cameras [1-4].

3. IMAGE COMPRESSION TECHNIQUES

Compression techniques can be grouped into two main classes: Compression techniques without loss of information (Lossless Compression). And Compression techniques with loss of information (Lossy Compression). In the first type, the compressed images are regenerated without errors; that is, they are the same as the original. While in the second type, the reconstructed images are different from the original image. In each classification, there are compression strategies or algorithms that stand out, which are presented in the following subsections along with their characteristics [12, 13].

3.1. Image compression techniques without loss of information (lossless compression)

In this type, the images are considered based on entropy, a technique that encodes the data without knowing their nature, they are general purpose and where the reconstructed image is the same as the original image. These techniques stand out because they employ statistical methods [6, 14, 15], which allows lossless compression. Some of these techniques are Run-length encoding (RLE), Huffman coding, arithmetic coding, and Lempel-Ziv. These techniques are described below:

– RLE

It is the simplest method of image compression. It is useful in images whose sequence of characters are repeated. It consists of storing the number of characters that are repeated, followed by the character. For example, if we have a line in an image that starts with a white or empty character, followed by 10 characters *y, it ends with another white or empty character; the representation of the line will be done as follows: 1B10 * 1B. It is noted that 7 characters are used to encode the string, while in the original form, 12 characters are used. This method is also used in combination with others, so the JPEG format uses it after transforming and quantifying blocks of images [16-18].

– Huffman coding

It is a technique that consists of assigning code of shorter bits to the data with a higher frequency of appearance and more extended codes to those that appear with less regularity. It is widely used due to its simplicity, high speed, and not having patent problems. It was developed by David Huffman in 1951 [19-21]. The algorithm consists of creating a binary tree from the bottom up:

- a) An alphabet of n symbols is taken; each symbol has an associated frequency of appearance.
- b) The symbols arranged from highest to lowest frequency are placed, which constitute the leaf nodes of the binary tree.
- c) The lower frequency symbols are grouped in pairs, and the sum of their probabilities is assigned to the parent node. This action is carried out until there are no leaf nodes left to join any upper node, and the binary tree has been formed.
- d) The edges of each tree branch are labeled, with zero on the left, and with one on the right edge.
- e) Huffman code is produced for that alphabet and those frequencies, with bits traversed from the root to the leaves.

In the example of Figure 2, the binary code that is generated for the alphabet shown at the base of the structure, and that appears along with its frequencies are observed.

– Arithmetic coding

It encodes a sequence of symbols using a binary representation; the series of bits is obtained from intervals that have real values between range 0 and 1. The following steps are considered in this coding technique without loss of information:

- a) An alphabet of n symbols is taken; each symbol has an associated occurrence frequency, or probability of appearance of the symbol, the probability in the sequence of symbols is not necessarily presented in order.
- b) The cumulative probability for each symbol of a sequence is calculated, the probability that becomes for each symbol processed in an increasingly smaller value.
- c) Each symbol is assigned its rank that has its cumulative probability as an upper limit and as a lower limit, the probability of the previous symbol of the sequence or zero if it is the first symbol [7, 22, 23].
- d) The result is translated into binary code. The symbols most likely use a few bits; for example, 0.875 translates to 1110, while 0.25 to 01.

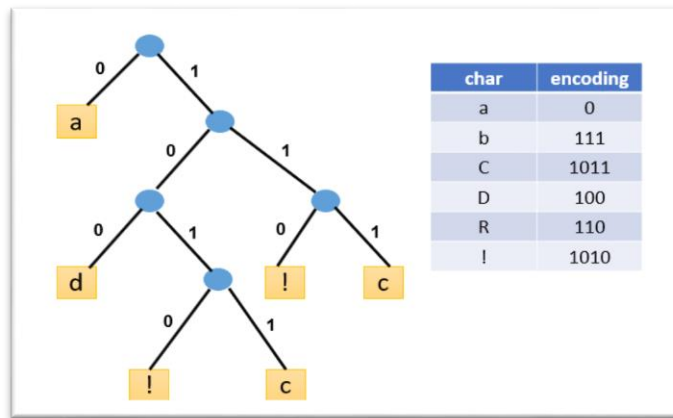


Figure 2. Example of Huffman code

– **Lempel-Ziv**

The Lempel-Ziv (LZ) algorithm performs an analysis from strings or words of a given alphabet, whose lengths do not exceed a prescribed integer L. Subsequently, these strings or words are assigned sequentially to a single fixed-length word code LZ [24] see the example in Table 1.

Table 1. Example of arithmetic coding

Sequence of symbol	probability	Cumulative probability	rank
A	.2	.2	[0, .2]
B	.4	.6	[.2, .6]
C	.1	.7	[.6, .7]
D	.2	.9	[.7, .9]
#	.1	1.0	[.9, 1.0]

The chains are selected in such a way that they have a close probability of occurrence. As a result, symbols that frequently occur, such as space and zero, are grouped in chains of longer lengths, while infrequent symbols, such as z, appear in short chains [25-27]. This strategy is effective due to the frequency of symbols, repetition of characters, and patterns of high use. It is an incremental analysis technique in which the coding process is carried out with a learning process for characteristics of different sources, for example, strings containing characters that are repeated gradually can be learned, like chains (cas, casita, casona, 0, 00, 000) [25-27]. The LZ algorithm analyzes each string and constructs phrases by adding one symbol at a time to an existing string when a correspondence occurs. Subsequently, each chain is assigned a code. For example, for the chains presented in the previous paragraph, they can be assigned codes 1, 2, 3, 4, 5, and 6, respectively. The LZW technique (Lempel-Ziv-Welch) is a variant of the LZ and is one of the most commonly used in practice, in this case, a pointer is used, instead of symbol code [28].

3.2. Image compression techniques with loss of information (lossy compression)

In this classification, the reconstructed image or sequence is different from the original image. They are mainly used when images have redundant information that can be eliminated or reduced; for example, the color of the sky in a photo is usually uniform and blue. In these techniques, sometimes, it is also interesting to code the brightness level of a sample (luminance or Y component) and color differences (blue, red, and green chrominance, or Cb, Cr, Cg components) [12, 15, 29, 30]. The reduction is made using source-based encoding techniques, which encode the data based on the characteristics and properties of their images, allow high compression rates, and are generally for specific purposes. Some techniques that stand out are transformation coding, quantization vector, and fractal compression [25, 31, 32].

– Transformation coding

The basic idea in this technique is to use a transform such as discrete Fourier to match the image with a set of coefficients of the transform. A quantification process is applied to these coefficients, where generally, a significant number of the coefficients have small values that are insignificant, which can be eliminated through a process known as quantization, resulting in the loss of information, even if this does not imply appreciable distortion of the image. In this way, a small number of image data is obtained, to which a lossless coding technique is usually applied to improve the results [28]. The discrete cosine transforms

(known as DCT for its acronym in English) is more frequently used for image compression, due to its ability to package information, because it packages most of the information into the smallest number of coefficients; DCT also minimizes the visibility of the boundaries between sub-images [33-37]. The coefficients in this technique are calculated from (4):

$$T_{ij} = \begin{cases} \sqrt{\frac{1}{n}} \cos \frac{(2j+1)ix}{2n} & i = 0, 0 \leq j < n \\ \sqrt{\frac{2}{n}} \cos \frac{(2j+1)ix}{2n} & 0 < i < n, 0 \leq j < n \end{cases} \quad (4)$$

– Quantization vector

The central idea is to select a representative set of an image. Below are the basic steps that the documented technique follows with an example:

- The image is divided into fixed-size blocks called vectors
- A table containing different vectors found in the original image is constructed. You can direct the vectors in this image to the vectors in the table. If the table includes a much smaller number of vectors than the original image because it includes repeating vectors, compression may be important.
- In this system, the coding, compression, can be a succession of indexes to the table, as seen in Figure 3.

For the coding of a set of images, using this technique, the table can be dynamically constructed. Also, techniques such as clustering can be used to perform vector classification [12, 38, 39].

– Fractal compression

A fractal is a semi-geometric object whose basic structure, fragmented or irregular, is repeated at different scales; for example, clouds, mountains, the circulatory system, coastal lines, or snowflakes are natural fractals; many images are like these objects. Fractal compression consists of transmitting images using functions. That is, given an image, from a set of images, the function f is applied: Image \Rightarrow Image such that $f(i)$ is similar to i . The process is completed by transmitting the coefficient that only identifies f .

There are several techniques for compressing fractal images, one of which consists of finding an iterated function system (IFS) that generates a set of transformations that carry the complete figure in each of its self-similar parts. The information on the image will be encoded in the IFS, where the repeated application of the transformations allows to obtain an image quite close to the original. It is a lossy compression technique. In Figure 4, the figure of a fern is presented, below is an example of fractal image compression as applied to the infamous Lena image.

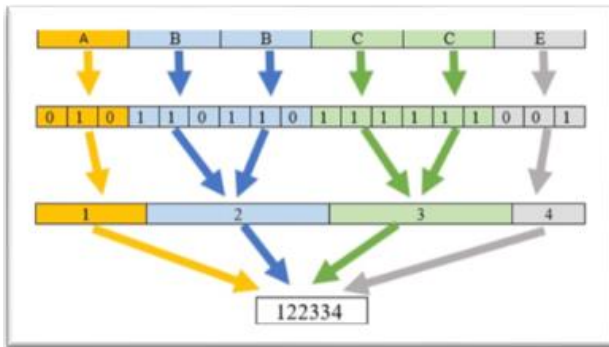


Figure 3. Example of quantization coding



Figure 4. Example image for fractal compression

The application of fractal techniques for the compression of digital images was introduced by Michael Barnsley and Arnaud Jacquin in 1988. Jacquin proposed to consider the images as a collection of related transformations of small image domains, while Barnsley suggests that images be stored as a collection of transforms, whose number determines the compression rate [12, 38, 39].

4. FORMATS OF IMAGE FILES

A format is a standard way of encoding data from an image to store or transmit it. However, there must be some method to convert to zeros and ones that are the language of the computer. In this part, the two

categories of image files are developed: bitmap and vectors, and the most commonly used image formats are presented; in the latter case the JPEG (Joint Photographic Experts Group) technique is shown in more detail.

4.1. Bitmaps and vectors

All image files belong to one of the two basic categories: bitmap or vectors. An intuitive way to understand a bitmap is to compare it with a computer monitor, display images as a set of individual colored pixels. Each pixel is a cell in the bitmap [33-37, 40, 41]. Vector image files are a set of vectors based on mathematical equations, which geometrically describe an image. The equations correspond to points, lines, curves and shapes, or polygons. They can also specify the size, thickness, position, color and fill with the geometric lines or shapes. To build an image requires programs that use vectors or mathematical formulas. Images made with vectors are generally of higher quality than using bitmaps. The formulas preserve the quality of the images at different scales, sizes, and details, while in bitmaps, such quality is lost, in Figure 5 the effect of increasing the scale of the original figure is observed seven times, in where it is observed that the image quality is not modified using a vector file while using a bitmap file the image quality is lost. However, vectors and bitmaps complement each other, as vectors can contain bitmaps as data and, likewise, vectors can be shown by bitmaps. Bitmaps are generally used in photographs or images of real photos, while vectors are mostly used in composition and graphic design [1-4].

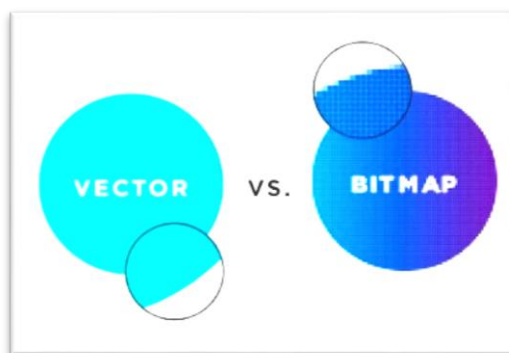


Figure 5. Effects of bitmap image files and vectors image

4.2. Formats

There are hundreds of image formats. However, the best known and belonging to the category of bitmaps are:

- JPEG (Joint Photographic Experts Group) formats

It is an ISO standard format, whose origin comes from the Joint Photographic Expert Group, which is designed for compression of images from photographs and real scenes, color or grayscale, and continuous tones. It allows adjusting the degree of compression, if the compression is low, images very similar to the original are registered, but the file size is large [42]. JPEG uses a lossy compression technique. Figure 6 shows the steps followed by the technique, which are described in the following paragraphs. The JPEG method encodes an image in three stages, which are described below:

Stage 1. Image preparation

- A color space transformation is performed. Color images are transformed from RGB space to YUV space (luminance and prominence).
- Subsampling, allows color reduction to obtain files of smaller sizes than the original.
- In block formation, the image is divided into blocks of 8x8 pixels.

Stage 2. Source coding, loss coding

- The discrete transformation of cosine or DCT is applied, which is applied to each image block, thus obtaining a frequency domain (coefficient matrix).
- Quantification, each coefficient of the 8x8 matrix is divided by a constant of the quantization matrix and rounded to its nearest integer. The less representative coefficients are eliminated, resulting in loss of image information and, therefore, its quality [42].
- GIF (Graphics Interchange Format)

It is limited to 256 colors and allows you to store static images as simple diagrams or logos with areas of solid color; it also saves images such as cartoons and simple animations. It uses Lempel-Ziv-Welch (LZW), which is an image compression method without loss of information [10].

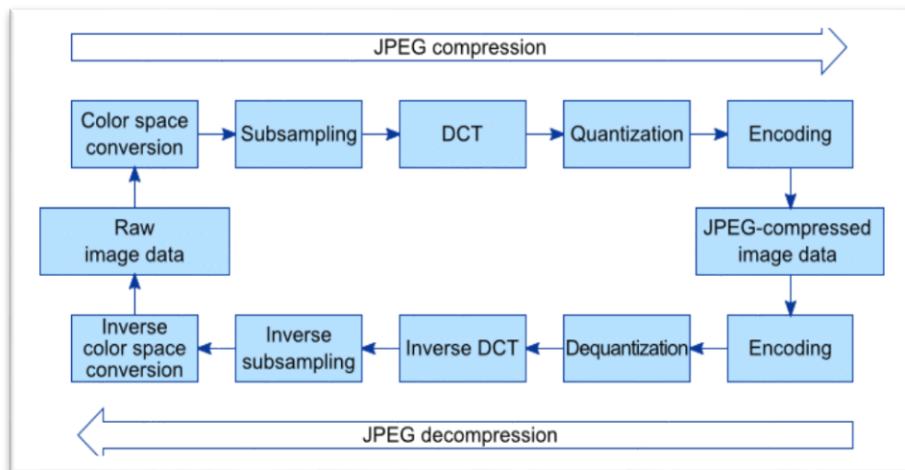


Figure 6. The sequence of steps followed by the JPEG method

– PNG (Portable Network Graphics)

It is based on a lossless compression algorithm; it belongs to the bitmap category. This format was developed in large part to solve the deficiencies of the GIF format; it is not subject to patents. It supports up to 16 million colors and allows storing images in grayscale, RGB (real colors), and provides transparency levels. It is very suitable for graphics but does not support animation. They use the.PNG extension.

– TIFF (Tagged Image File Format)

It is a tagged image file format. It belongs to the bitmap category. Created by Aldus in the mid-80s, it is currently part of Adobe Systems. It supports grayscale and real color images, even at 16 bits per pixel. It is a very popular format and used in most applications of image manipulation, composition, scanning, fax, optical character recognition (OCR). It owes its name to the fact that TIFF files contain, in addition to the data of the image itself, "tags" in which information about the characteristics of the image is archived, which is used for further processing. Supports various forms of compression with or without loss of information, such as JPEG and LZW, respectively. Use extension TIF or TIFF.

– BMP (Windows bitmap)

The data is encoded with lossless compression, so the file size is considerable. Handles colors up to 24 bits deep. They are used in Microsoft programs in graphics files such as icons and wallpaper.

5. CONCLUSIONS

In this paper, a brief description is made of the main image compression techniques and the most commonly used standard image coding formats. Previously, the fundamental concepts and definitions that characterize the images were presented. Image compression is a critical issue in digital image processing because it allows you to store or transmit image data efficiently. There are several traditional and current techniques that allow compression. In this work the best known and used have been described.

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REFERENCES

- [1] S. G. S. V. R. K. Rao, B Priyanka, Rupalin Nanda "Effective Analysis of Human Facial Appearance using JAFFE Images," *International Journal of Advanced Trends in Computer Science and Engineering*, vol. 7, no. 6, no. 2278-3091, 2018

- [2] A. A. J. Altaay, S. B. Sahib and M. Zamani, "An Introduction to Image Steganography Techniques," *2012 International Conference on Advanced Computer Science Applications and Technologies (ACSAT)*, Kuala Lumpur, pp. 122-126, 2012.
- [3] D. p. Tian, "A Review on Image Feature Extraction and Representation Techniques," *International Journal of Multimedia and Ubiquitous Engineering*, vol. 8, no. 4, 2013.
- [4] J. Tao, S. Li, X. Zhang and Z. Wang, "Towards Robust Image Steganography," in *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 29, no. 2, pp. 594-600, Feb. 2019.
- [5] A. Almohammad, R. M. Hierons and G. Ghinea, "High Capacity Steganographic Method Based Upon JPEG," *2008 Third International Conference on Availability, Reliability and Security*, Barcelona, pp. 544-549, 2008.
- [6] Huizhuo Niu, Yuanyuan Shang, Xinhua Yang, Dawei Xu, Baoyuan Han and Chuan Chen, "Design and research on the JPEG-LS image compression algorithm," *2010 Second International Conference on Communication Systems, Networks and Applications*, Hong Kong, pp. 232-234, 2010.
- [7] S. Muttoo and S. Kumar, "Data hiding in JPEG images," *International Journal of Information Technology (IJIT)*, vol. 1, pp. 13-16, 2009.
- [8] A. Cheddad, J. Condell, K. Curran, and P. Mc Kevitt, "A Comparative Analysis of Steganographic Tools," in *Proceedings of the Seventh IT&T Conference. Institute of Technology Blanchardstown, Dublin, Ireland. 25th*, Citeseer, pp. 29-37, 2007.
- [9] I. J. Cox, J. J. Kilian, and T. G. Shamoan, "Secure spread spectrum watermarking for multimedia data," ed: Google Patents, 2001.
- [10] G. Swain and S. K. Lenka, "A Novel Approach to RGB Channel Based Image Steganography Technique," *Int. Arab J. e-Technol.*, vol. 2, no. 4, pp. 181-186, 2012.
- [11] G. Swain and S. K. Lenka, "A technique for secret communication using a new block cipher with dynamic steganography," *International Journal of Security and Its Applications*, vol. 6, no. 2, pp. 1-12, 2012.
- [12] O. G. Roshidi Din, Alaa Jabbar Qasim, "Analytical Review on Graphical Formats Used in Image Steganographic Compression," *Indonesian Journal of Electrical Engineering and Computer Science (IJECS)*, vol. 12, no. 2, pp. 441-446, 2018
- [13] A. J. Qassim and Y. Sudhakar, "Information Security with Image through Reversible Room by using Advanced Encryption Standard and Least Significant Bit Algorithm," *International Journal of Advances in Computer Science and Technology*, vol. 4, no. 4, pp. 93-97, April 2015.
- [14] S.-G. Park, "Adaptive Lossless Video Compression," thesis, Purdue University, USA, 2004.
- [15] P. Kavitha, "A Survey on Lossless and Lossy Data Compression Methods," *International Journal of Computer Science & Engineering Technology*, vol. 7, no. 03, pp. 110-114, 2016.
- [16] Zhicheng Ni, Y. Q. Shi, N. Ansari, Wei Su, Qibin Sun and Xiao Lin, "Robust lossless image data hiding," *2004 IEEE International Conference on Multimedia and Expo (ICME) (IEEE Cat. No.04TH8763)*, Taipei, 2004, pp. 2199-2202 Vol.3.
- [17] D. Schonberg, S. Draper and K. Ramchandran, "On Compression of Encrypted Images," *2006 International Conference on Image Processing*, Atlanta, GA, 2006, pp. 269-272.
- [18] H. W. Tseng and C. C. Chang, "High Capacity Data Hiding in JPEG-Compressed Images," *Informatica*, vol. 15, no. 1, pp. 127-142, 2004.
- [19] A. Al-Azawi and M. A. Fadhil, "Arabic text steganography using kashida extensions with huffman code," *J Applied Sci*, vol. 10, pp. 436-439, 2010.
- [20] G. Satyavathy and M. Punithavalli, "LSB, 3D-DCT and Huffman Encoding based Steganography in Safe Message Routing and Delivery for Structured Peer-to-Peer Systems," *IJCA Special Issue on Artificial Intelligence Techniques*, pp. 1-5, 2011.
- [21] M. Sharma, "Compression using Huffman coding," *IJCSNS International Journal of Computer Science and Network Security*, vol. 10, no. 5, pp. 133-141, 2010.
- [22] A. Choodarathnakara, "A JPEG-Discrete Cosine Transformation Based Coding Technique for Image Data," *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)*, vol. 4, no. 4, pp. 1342-1348, 2015.
- [23] M. Kumar, "Steganography and steganalysis of joint picture expert group (JPEG) images," University of Florida, 2011.
- [24] N. Johnson and S. Jajodia, "Steganalysis of images created using current steganography software," in *Information Hiding*, Springer, pp. 273-289, 1998.
- [25] S. A. Taleb, H. M. Musafa, A. Khtoom, and K. Gharaybih, "Improving LZW image compression," *European Journal of Scientific Research*, vol. 44, no. 3, pp. 502-509, 2010.
- [26] Michael J. Knieser, Francis G. Wolff, Chris A. Papachristou, Daniel J. Weyer, and David R. McIntyre, "A Technique for High Ratio LZW Compression," In *Proceedings of the conference on Design, Automation and Test in Europe-Volume 1 (DATE '03)*, IEEE Computer Society, USA, 10116, 2003.
- [27] T. Kida, M. Takeda, A. Shinohara, M. Miyazaki and S. Arikawa, "Multiple pattern matching in LZW compressed text," *Proceedings DCC '98 Data Compression Conference (Cat. No.98TB100225)*, Snowbird, UT, USA, pp. 103-112, 1998.
- [28] F. Q. A. Al-Yousuf and R. Din, "Review on secured data capabilities of cryptography, steganography, and watermarking domain," *Indonesian Journal of Electrical Engineering and Computer Science (IJECS)*, vol. 17, no. 2, pp. 1053-1059, 2020.
- [29] A. Kaur and J. Kaur, "comparison of DCT and DWT of Image Compression Techniques," *International journal of engineering research and development*, vol. 1, no. 4, pp. 49-52, 2012.

- [30] V. M. Sai Virali Tummala, "Comparison of Image Compression and Enhancement Techniques for Image Quality in Medical Images," Blekinge Institute of Technology: thesis, 2017.
- [31] M. A. Roth and S. J. Van Horn, "Database compression," *ACM Sigmod Record*, vol. 22, no. 3, pp. 31-39, 1993.
- [32] M. Nelson and J.-L. Gailly, "The data compression book," M & t Books New York, 1996.
- [33] R. K. Megalingam, M. M. Nair, R. Srikumar, V. K. Balasubramanian, and V. S. V. Sarma, "A Comparative Study on Performance of Novel, Robust Spatial Domain Digital Image Watermarking with DCT Based Watermarking," *International Journal of Computer Theory and Engineering*, vol. 2, no. 4, p. 647, 2010.
- [34] C.-C. Lin and P.-F. Shiu, "High capacity data hiding scheme for DCT-based images," *Journal of Information Hiding and Multimedia Signal Processing*, vol. 1, no. 3, pp. 220-240, 2010.
- [35] K. B. S. Kumar, K. B. Raja, R. K. Chhotaray and S. Pattnaik, "Coherent steganography using Segmentation and DCT," *2010 IEEE International Conference on Computational Intelligence and Computing Research*, Coimbatore, pp. 1-6, 2010.
- [36] A. K. Katharotiya, S. Patel, and M. Goyani, "Comparative analysis between DCT & DWT techniques of image compression," *Journal of information engineering and applications*, vol. 1, no. 2, pp. 9-17, 2011.
- [37] T. Pevny and J. Fridrich, "Merging Markov and DCT features for multi-class JPEG steganalysis," in *Electronic Imaging 2007*, International Society for Optics and Photonics, pp. 650503-650503-13, 2007.
- [38] R. Din, M. Mahmuddin, and A. J. Qasim, "Review on Steganography Methods in Multi-Media Domain," *International Journal of Engineering & Technology*, vol. 8, no. 1.7, pp. 288-292, 2019.
- [39] R. Din and A. J. Qasim, "Steganography analysis techniques applied to audio and image files," *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 8, no. 4, pp. 1297-1302, 2019.
- [40] N. M. S. Kafri and H. Y. Suleiman, "Bit-4 of frequency domain-DCT steganography technique," *2009 First International Conference on Networked Digital Technologies*, Ostrava, pp. 286-291, 2009.
- [41] A. Al-Haj, "Combined DWT-DCT digital image watermarking," *Journal of computer science*, vol. 3, no. 9, pp. 740-746, 2007.
- [42] J. Q. Al-Maliki and A. J. Q. Al-Maliki, "The Processes and Technologies of 3D Printing," *International Journal of Advances in Computer Science and Technology*, vol. 4, no. 10, pp. 161-165, 2015.

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