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An Extensive Analysis of Digital Image Compression Techniques Using Different Image Files and Color Formats

Fauziah [a,*], Dhieka Avrilia Lantana [a], Nurhayati [a], Ira Diana Sholihati [a], Ratih Titi Komala Sari [a], Billy Hendrik [b]

[a] *Faculty of Computer Science, Universitas Nasional, Indonesia*
[b] *Faculty of Computer Science, Universitas Putra Indonesia "YPTK" Padang, Padang, Indonesia*
*Corresponding author: *fauziah@civitas.unas.ac.id*

***Abstract*—Data storage on the device can affect the access speed of the device used; for example, files, images, and data will affect the performance of the device, become slow to access, difficult to open, download, and save images, files, because the available storage capacity is limited, with the problems that arise, an image compression technique is needed to minimize storage space and speed up the access. The compression technique can reduce a file, image, and data size but does not reduce the existing image's quality or lower the threshold during the sending or receiving. This research aims to reduce the size, speed up the process of accessing data on devices, and, more importantly, minimize memory space. It can also affect the bandwidth used when sending and receiving files and can speed up the process of sending from source to destination. The method used in this study is Lossy Compression, lose less Compression by comparing RLE, Huffman, and LZW using different image file types. For the Lossless Technique, the best quality reduction ratio is in binary image types, whether using a background or not using a background. The best results obtained are 99.10% (PNG Compression). Using the BMP file extension type, the recommended reduced ratio is lossy compression with format image BMP (JPG compression) for binary image using Lossless Compression has a good reduced ratio compression with an average of 99%.**

***Keywords*— Algorithm; compression; Huffman; LZW; RLE.**

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I. INTRODUCTION

In general, every application that exists today requires images with various formats and sizes, which will certainly affect the computing process, so an image compression technique is needed so that the application does not require large memory and takes a long time to execute. Using lossy and lossless techniques to carry out the image compression process. The formats file in images that are commonly used so that appropriate compression results can help application makers and programmers.

Image processing is a variety of techniques to manipulate and modify images to improve image quality through increasing contrast, image restoration, color transformation, rotation, scaling, translation, carrying out the process of retrieving information and recognition [1],[2],[3]. Image compression can reduce the memory used when storing and sending becomes smaller to process transmission but does not reduce the image quality. Besides, it can reduce the amount of data needed to represent the digital image [4],[5],[6]. Both lossless and lossy compression techniques have their respective advantages, the results of the existing image, and can reduce the existing distortion of the image [7],[8],[9].

In general, digital images can be compressed, one of which is with lossy techniques with much greater compression results when compared to using lossless techniques. Using compression techniques still produces good-quality images after being compressed with low bit rates [10], [11]. Image compression, also known as image compression, is a process to minimize the number of bits representing an image, the compression ratio of the data, and the image quality used [12]-[15]

Image compression is essential for many fields, such as communications. One form of compression used is the Run-length encoding (RLE) method, which is a lossless data compression process using a sequence of data from the number of existing data elements [16]-[19]. DCT is one of the methods used in the image compression process, namely the lossy compression technique, and is a digital compression technique. [20],[21],[22] This image compression aims to reduce data sets that are similar in images so that they can be stored with a smaller size or transmitted efficiently and to find image representations with reduced pixel correlation. In image compression, DCT receives input in the form of an image matrix, which then converts it into a frequency matrix with the same size [23]- [26]. The image compression process using the HAAR Discrete Wavelet algorithm is a coding process of a simple and fast compression algorithm with a higher compression ratio and PSNR value [27],[28].

Previously, research on Comparative and improvement analysis of digital image compression algorithms with various image files [29],[30]. The digital image compression process is very important to use and with different techniques, both lossy and lossless, including the RLE technique, Huffman encoding, wavelet, LZW, and other techniques based on compression ratios with different results and based on the images used in each study[31],[32],[33].

Research that has been carried out using the LZW and Huffman methods shows that the results with the LZW method are more efficient for compression ratios, and the compressed image type is a PNG image [34] [35]. In the compression process, it is needed to facilitate data processing to minimize the use of resources and time. [36], [37], [38] Still, the results obtained are more optimal by using a lossless method of data compression that is fixed and does not eliminate the information contained in the data, for example, image data that is used properly using the Huffman method to get optimal results [39], [40], [41].

The image processing process will certainly help the image compression process so that any information in the image remains. Based on the background that has been explained both in terms of lossless and lossy techniques with various algorithms that have been implemented from previous research but only using limited file types, the novelty and contribution of this research is to use eight different image formats, namely (BMP, TIFF, HDR, SVG, JPGM PNG, HEIG and GIF) and using the RLE, Huffman and LZW algorithms, which compares which compression process is more optimal using different color formats.

II. MATERIALS AND METHOD

The research stages for image compression will compare the different methods and the steps as follows:

A. *Image Acquisition*

This stage is the stage of collecting image (object) data, which is the initial input to this system. The image is taken using iPhone 14 Pro 48 megapixels without a flash. The image was taken with the background. The image used in this research has many extension files (BMP, TIF, HDR, JPG, PNG) and uses jpg quality compression 100. Figure 1 is a sample image for compression with many extension files (BMP, TIF, HDR, JPG, and PNG)—the next image processing step.

Fig. 1 Sample data collecting image with many extension files

B. *Image Processing*

Image processing is a method to perform operations on images, obtain enhanced images, or extract useful information from them. Input to image processing is an image, and the output can be an image or the characteristics/features associated with the image.

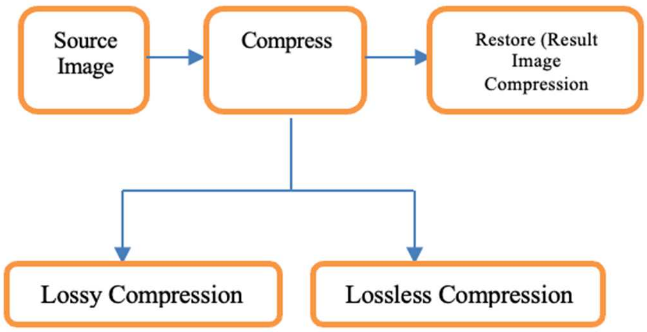

Fig. 2 Stage Image Compression

Figure 2 stages the image compression with lossy compression and Lossless compression. The image compression process uses several images with different formats and performs the following steps:

- RGB image with background.
- RGB image without background.
- Grayscale image with background.
- Grayscale image without background.
- Image Binary with background.
- Image Binary without background.

From figure 3, RGB (original image use background and types save the image with extension BMP, TIF, HDR, JPG, PNG, the different file aims to understand the image compression process using 2 techniques, both lossy and lossless, so that a smaller storage image file is obtained without reducing the image quality and information contained in the image used.

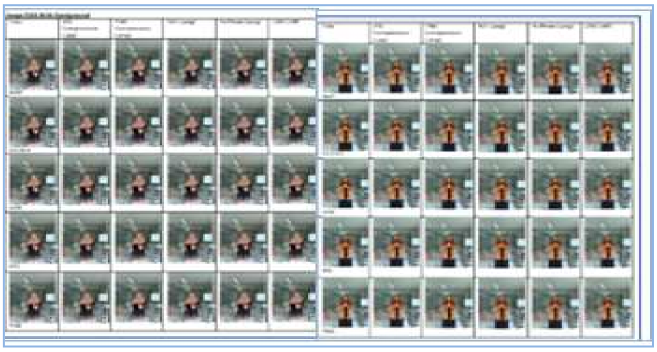

Fig. 3 RGB Image with Background

From figure 4 to figure 8, many images for testing and implementation were compressed with lossy and lossless techniques. From Figure 4, the real image RGB with background and types of file extension are BMP, TIF, HDR, JPG, and PNG until figure 9, the original image processing is carried out from the original image (RGB) to a grayscale and binary image with the same file types.

Fig. 4 RGB Image with Background

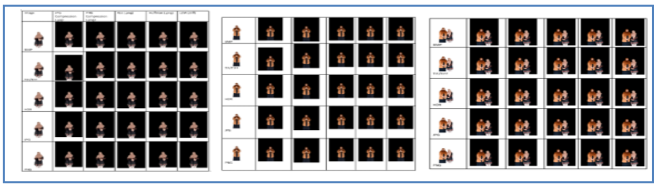

Fig. 5 RGB Image without Background

Fig. 6 Grayscale with Background

Fig. 7 Binary Image with Background

Fig. 8 Binary Image without Background

III. Results and Discussions

A. Scenario Testing RGB Image

From table 1, the compression results using RGB image files with various file types, namely BMP, TIF, HDR, SVG, JPG, PNG, HEIC, and GIF, seen in the test results on BMP, TIF, and HDR file types the compression ratio is very good reaching 87%, using files with the JPG compression file type is not recommended for the compression ratio, as well as for the SVG, HEIG and GIF file types in the data in this study (scenario RGB with Background).

TABLE I
Lossy compression RGB image

Format	**Original Size (MB)**	**Lossy Compression**	
		JPG (MB)	**JPG (%)**
BMP	36.5	4.4	87.95
TIF/.TIFF	36.5	4.5	87.67
HDR	36	4.4	87.78
SVG		Not Available	
JPG	4.3	2.1	51.16
PNG	8.9	4.4	50.56
HEIC		Not Available	
GIF		Not Available	

TABLE II
Lossless compression RGB image

Format	**Original (MB)**	**Lossless Compression**							
		PNG (MB)	**PNG (%)**	**PNG with RLE (MB)**	**PNG with RLE (%)**	**PNG with Huffman (MB)**	**PNG with Huffman (%)**	**TIFF With LZW (MB)**	**TIFF with LZW (%)**
BMP	36.5	4.4	87.95	14.6	60.00	14.6	60.00	12.5	65.75
TIF/.TIFF	36.5	4.5	87.67	14.6	60.00	14.6	60.00	12.5	65.75
HDR	36	4.4	87.78	14.7	59.17	14.7	59.17	12.7	64.72
SVG					Not Available				
JPG	4.3	2.1	51.16	3.6	16.28	3.6	16.28	2.5	41.86
PNG	8.9	4.4	50.56	6.6	25.84	6.6	25.84	6.5	26.97
HEIC					Not Available				
GIF					Not Available				

Error! Reference source not found. From table 2, shows lossless compression with RGB image for Lossless compression 87.85% PNG compression, 60% PNG compression with RLE, 60% PNG compression with Huffman, and 65.75% TIFF compression with LZW (scenario RGB Image with background).

B. Scenario Testing Grayscale, Binary Image with Background

From table 3, it can be seen that using the lossy compression technique is at jpg compression is 89.14%, and by using lossless compression techniques. It is 87.95% (PNG compression), 80.00% PNG Compression with RLE, 60.00% PNG compression with Huffman, and 65,757% TIFF compression with LZW. (Scenario Grayscale image with Background).

TABLE III
GRAYSCALE IMAGE WITH LOSSY AND LOSSLESS COMPRESSION

Format	Original (MB)	Lossy Compression		Lossless Compression							
		JPG (MB)	JPG (%)	PNG (MB)	PNG (%)	PNG with RLE (MB)	PNG with RLE (%)	PNG with Huffman (MB)	PNG with Huffman (%)	TIFF with LZW (MB)	TIFF with LZW (%)
BMP	12.2	3.9	68.03	4.4	87.95	10.6	13.11	14.6	60.00	12.5	65.75
TIF/.TIFF	6.4	3.9	39.06	4.5	87.67	5.6	80.00	14.6	60.00	12.5	65.75
HDR	35.9	3.9	89.14	4.4	87.78	14.7	59.05	14.7	59.17	12.7	64.72
SVG	Not Available										
JPG	2.4	1.9	20.83	1.3	45.83	1.6	33.33	3.6	-50.00	2.5	-0.18
PNG	5.5	3.9	29.09	4.4	50.56	2.6	52.72	6.6	-20.00	6.5	-0.185
HEIC	Not Available										
GIF	Not Available										

TABLE IV
BINARY IMAGE WITH LOSSY AND LOSSLESS COMPRESSION

Format	Original (MB)	Lossy Compression		Lossless Compression							
		JPG (MB)	JPG (%)	PNG (MB)	PNG (%)	PNG with RLE (MB)	PNG with RLE (%)	PNG with Huffman (MB)	PNG with Huffman (%)	TIFF with LZW (MB)	TIFF with LZW (%)
BMP	12.2	2.4	80.33	0.2	98.36	0.3	97.54	0.3	97.54	0.5	95.90
TIF/.TIFF	3.5	2.4	31.43	0.2	60.00	0.3	40.00	0.3	40.00	0.5	85.71
HDR	2.6	2.4	7.69	0.2	92.30	0.3	86.36	0.3	92.30	0.5	80.76
SVG	Not Available										
JPG	2.6	2.4	7.69	0.2	92.30	0.3	88.46	0.3	88.46	0.5	80.76
PNG	3.3	2.4	27.27	0.2	93.93	0.3	90.90	0.3	90.90	0.5	90.90
HEIC	Not Available										
GIF	Not Available										

Table 4 shows the results of image compression using a background compressed with binary images in a lossy compression technique of 80.33% for the compression reduction ratio of the image used. For the lossless technique, the results are a 98.36% reduction ratio for PNG compression, 97.54% for PNG Compression with RLE, 97.54% PNG Compression with Huffman, and 95.90%TIFF Compression with LZW.

C. Scenario Testing RGB, Grayscale, Binary Image without Background

The results obtained in table 5 for the type of RGB image without a background with a lossy technique get a reduction ratio of up to 96.30% in PNG Compression. In the Lossless compression ratio technique, the decrease reached a value of 93.56% PNG Compression, 92.19% PNG Compression with RLE, 92.19% PNG Compression with Huffman, and 90.26% TIFF Compression with LZW.

TABLE V
RGB IMAGE WITHOUT BACKGROUND WITH LOSSY AND LOSSLESS COMPRESSION TECHNIQUE

Format	Original (KB)	Lossy Compression		Lossless Compression							
		JPG (KB)	JPG (%)	PNG (KB)	PNG (%)	PNG with RLE (KB)	PNG with RLE (%)	PNG with Huffman (KB)	PNG with Huffman (%)	TIFF with LZW (KB)	TIFF with LZW (%)
BMP	7680.1	284.1	96.30	494.9	93.56	599.5	92.19%	599.5	92.19	748.4	90.26
TIF/.TIFF	645.9	270.9	58.06	492.3	23.78	597.7	7.46%	597.7	7.46	746.3	-15.54
HDR	1070.8	248.5	76.79	468.7	56.23	610.2	43.01%	610.2	43.01	738.2	31.06
SVG	Not Available										
JPG	744.6	247.7	66.72	464.1	37.67	609.2	18.18%	609.2	18.18	732.8	1.72
PNG	684.6	284.1	58.50	494.9	27.71	599.5	12.43%	599.5	12.43	704.4	-2.89
HEIC	Not Available										
GIF	Not Available										

TABLE VI
GRAYSCALE IMAGE WITHOUT BACKGROUND WITH LOSSY AND LOSSLESS COMPRESSION TECHNIQUE

Format	Original (KB)	Lossy Compression		Lossless Compression							
		JPG (KB)	JPG (%)	PNG (KB)	PNG (%)	PNG with RLE (KB)	PNG with RLE (%)	PNG with Huffman (KB)	PNG with Huffman (%)	TIFF with LZW (KB)	TIFF with LZW (%)
BMP	1921.1	232.3	87.91	196.9	89.75	207.4	89.20	207.4	89.20	298.8	84.44
TIF/.TIFF	298.1	222.4	25.39	195.7	34.35	206.4	30.76	206.4	30.76	298.1	0.00
HDR	1093.4	200.5	81.66	198.3	81.86	212.4	80.57	212.4	80.57	305.9	72.02
SVG	Not Available										
JPG	339.1	200.5	40.87	198	41.61	212.3	37.39	212.3	37.39	305.5	37.39
PNG	307.4	232.3	24.43	196.9	35.94	207.4	32.53	207.4	32.53	298.9	2.76
HEIC	Not Available										
GIF	Not Available										

Table 6 shows the results obtained using a grayscale image without background with lossy and lossless compression techniques, with a reduction ratio of 87.91% JPG Compression in the Lossy technique. In the Lossless technique, 89.75% PNG Compression, 89.20% PNG compression with RLE and, 89.20% PNG Compression with Huffman, 84.44% TIFF Compression with LZW.

TABLE VII
BINARY IMAGE WITHOUT BACKGROUND WITH LOSSY AND LOSSLESS COMPRESSION TECHNIQUE

Format	Original (KB)	Lossy Compression		Lossless Compression							
		JPG (KI	JPG (%)	PNG (KB)	PNG (%)	PNG with RLE (KB)	PNG with RLE (%)	PNG with Huffman (KB)	PNG with Huffman (%)	TIFF with LZW (KB)	TIFF with LZW (%)
BMP	1921.1	172.6	91.02	17.2	99.10	21.8	98.87	21.8	98.87%	54.2	97.18
TIF/.TIFF	153.6	125	18.61	16.4	91.27	21.3	86.13	21.3	86.13%	53.6	65.10
HDR	247.4	167.4	32.34	17.7	92.85	22.3	90.99	22.3	90.99%	56.7	77.08
SVG	Not Available										
JPG	216.4	167.5	22.59	19.8	90.85	22.3	89.69	22.3	89.69%	56.7	73.79
PNG	211.8	172.6	18.50	17.2	91.87	21.8	89.70	21.8	89.70%	54.2	74.40
HEIC	Not Available										
GIF	Not Available										

Table 7 shows the results obtained using a binary image without a background with lossy and lossless compression techniques, with a 91.02% JPG Compression reduction ratio in the Lossy technique. In the Lossless technique, 99.10% PNG Compression, 98.87% PNG compression with RLE and, 98.87% PNG Compression with Huffman, 97.18% TIFF Compression with LZW.

D. Chart Compression (RGB, Grayscale, and Binary Image with Background)

From figure 9, the results of jpg compression on the BMP file format type have a reduced ratio of 87.95% with RGB images. From figure 10, the results of jpg compression on the HDR file format type have a reduced ratio of 89.14% with Grayscale images. Figure 11 indicates a binary image, the result compression of 98.36% can reduce the ratio with BMP extension format file images.

Fig. 9 Result Image Compression RGB Image with Background

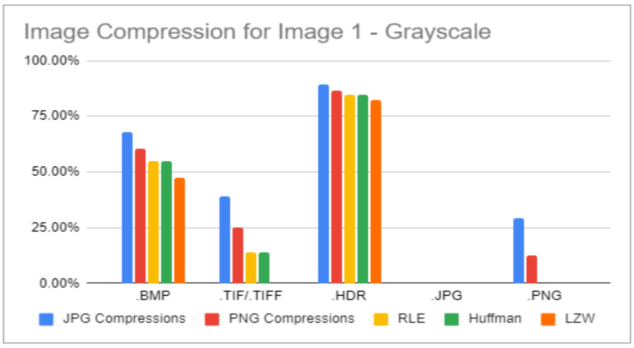

Fig. 10 Result Image Compression Grayscale Image with Background

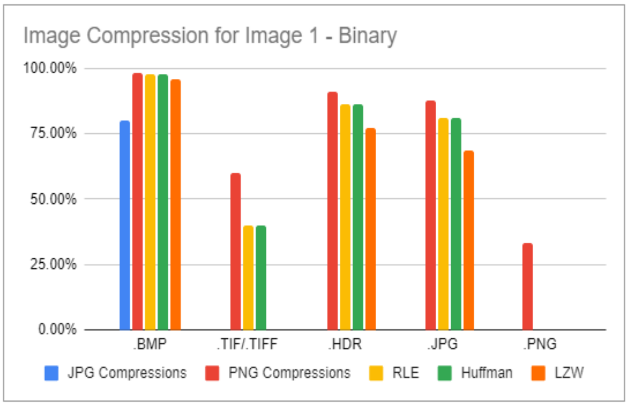

Fig. 11 Result Image Compression Binary Image with Background

E. Chart Compression (RGB, Grayscale, and Binary Image without Background)

Figure 12 shows the result of image compression RGB. It is clear that figure 12 shows the result for a reduced ratio of 96.30% (JPG Compression) with extension format image BMP. From figure 13, the results of PNG compression on the BMP file format type have a reduced ratio of 89.75% with Grayscale images. From figure 14, the results of PNG compression on the BMP file format type have a reduced ratio of 99.10 % with binary images. The results of the study can contribute to a reduction in the ratio for binary images with a better lossless compression technique that produces an average of 99% and provides a reduction in the compression ratio in the lossy technique with the BMP format (Jpg compression) to minimize the use of storage media, speeding up processing time but still produces good image quality.

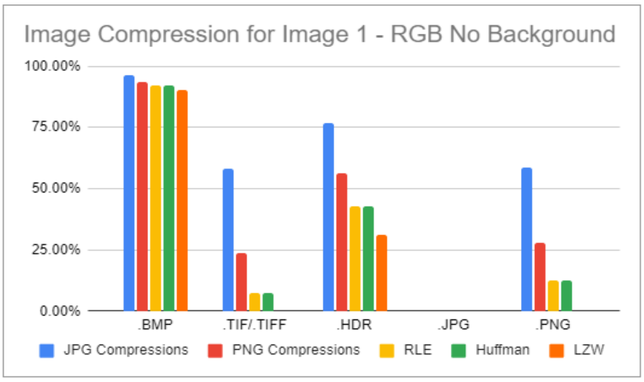

Fig. 12 Result Image Compression RGB Image without Background

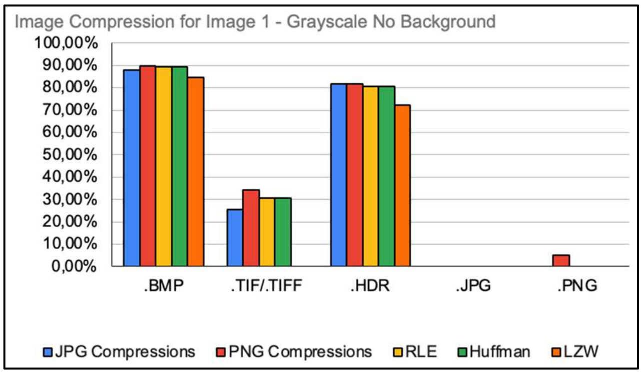

Fig. 13 Result Image Compression Grayscale Image without Background

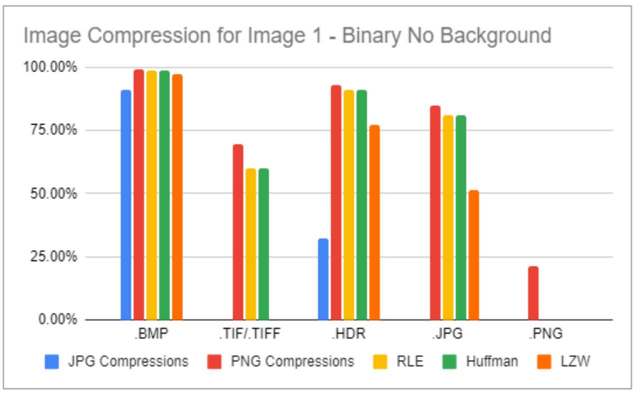

Fig. 14 Result Image Compression Binary Image without Background

IV. Conclusion

Based on the result, for the lossy technique, the best quality reduction ratio is in RGB and Grayscale image types, with the best value in BMP file types at 87.95%, Grayscale in HDR file types at 89.14%, and 80.33 %. The lossy technique has the best quality reduction ratio in the RGB image type with a value of 96.30% for the BMP file type, 87.91% for grayscale image types with the BMP image file extension, and 91.02% (JPG Compression). For the Lossless Technique, the best quality reduction ratio is in binary image types, whether using a background or not using a background. The best results obtained are 99.10% (PNG Compression).

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