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Image Compression Application Using Discrete Cosine Transform (DCT) Method

Amanda Rengganis, Muhammad Zulfansyuri Siambaton, Rachmat Aulia
Study Program Informatics Engineering
Faculty of Engineering, Universitas Islam Sumatra Utara, Medan, Indonesia,
amandarengganis2601@gmail.com; zulfansyuri@ft.uisu.ac.id; jackm4t@gmail.com

Abstract— The increasing demand for high-resolution digital images in various domains such as social media, healthcare, security, and facial recognition has intensified challenges related to large file sizes, impacting storage, transmission speed, and processing efficiency. Digital image compression offers a viable solution, with two primary approaches: lossless and lossy. Among lossy techniques, the Discrete Cosine Transform (DCT) is widely adopted, notably in the JPEG standard, for its ability to transform spatial-domain data into the frequency domain, preserving essential information while reducing redundant details. This study investigates the effectiveness of DCT-based compression in reducing file size while maintaining acceptable visual quality, highlighting its balance between storage efficiency and image fidelity.

Keywords : Digital Image Compression, Discrete Cosine Transform (DCT), Lossy Compression, Resolution, Efficiency.

1. INTRODUCTION

The rapid advancement of information and communication technology has driven a significant increase in the use of digital data, including data in the form of images or digital pictures. Today, digital images are widely used across various fields, such as social media, photography, healthcare, security, facial recognition systems, and image-based surveillance. The demand for high-resolution images with sharp details continues to grow alongside the development of digital devices such as cameras, smartphones, and other imaging technologies.

However, the use of high-resolution digital images results in very large file sizes. Large file sizes not only require substantial storage space but also slow down the transmission process over networks and reduce the efficiency of real-time image processing systems. Therefore, a method is needed to reduce image file sizes without compromising quality. One of the most common solutions to this problem is digital image compression.

Digital image compression is the process of reducing the amount of data required to represent an image. The primary goals of image compression are to reduce file size, improve storage efficiency, and accelerate data transmission, whether over local networks or the internet. Image compression can be performed using two approaches: lossless compression (compression without data loss) and lossy compression (compression with some loss of data). In many multimedia and digital communication applications, lossy methods are more widely used because they can achieve high compression ratios.

One of the most popular and widely used lossy image compression techniques is the Discrete Cosine Transform (DCT). DCT works by converting image data from the spatial domain to the frequency domain, allowing for the separation of low-frequency and high-frequency components. Low-frequency components, which contain essential image information, are retained, while high-frequency components, which often include noise or fine details, can be discarded or reduced.

The DCT method is widely implemented in compression standards such as JPEG due to its ability to achieve a good compression ratio with minimal quality degradation perceptible to the human eye. In other words, DCT allows efficient image compression without significantly sacrificing quality. Therefore, this research is highly relevant to examining the effectiveness of DCT in compressing digital images and assessing its impact on file size and image quality.

2. LITERATURE REVIEW

Digital images captured by cameras often suffer from various distortions or imperfections, such as unfocused lenses, the appearance of speckles caused by imperfect capture processes, uneven lighting resulting in inconsistent intensity, and low image contrast, which makes it difficult to separate objects from their backgrounds. Other disturbances may also occur due to particles or dirt on the lens or sensor. Although an image may contain rich information, such imperfections can degrade image quality, making it more difficult to interpret because the conveyed information becomes less clear. To overcome such noise, efforts must be made to improve image quality.

The significant influence of photographs in the media has increased their role in delivering accurate and wide-reaching information to the public. Photojournalism integrates images with news, serving as a means of communication through photography. In online media, the role of photographs has grown substantially, enabling them to complement news articles or even serve as news content themselves, possessing inherent news value.

Mathematically, an image can be defined as a continuous function of light intensity over a two-dimensional plane. To be processed by a digital computer, an image must be represented numerically with discrete values. A

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digital image can be represented by a two-dimensional matrix f(x, y) consisting of M columns and **N** rows, where the intersection of a column and a row is called a pixel (*picture element*), the smallest unit of a digital image.

Image compression is the process of reducing the amount of data required to represent a digital image. In the rapidly evolving digital world, storing and transmitting visual data such as images and videos demands significant storage space and bandwidth. Therefore, image compression techniques are essential for optimizing storage media usage and accelerating data transmission without significantly sacrificing quality. Image compression is a crucial component of digital image processing, particularly in communication systems, multimedia, web-based applications, mobile devices, and medical image archiving.

The Discrete Cosine Transform (DCT) is one of the most widely used frequency transformation methods in image compression, especially in lossy compression systems such as the JPEG standard. DCT works by converting the spatial representation of an image (pixel-based) into its frequency domain representation. This transformation enables the separation of image information based on its significance so that less important information—typically high-frequency components—can be discarded to save storage space without significantly affecting perceived visual quality.

3. RESULTS AND DISCUSSION

This study is a form of software engineering research with an applied experimental approach. The primary objective of this research is to design and implement a digital image compression application using the Discrete Cosine Transform (DCT) method and to evaluate its performance based on the compressed file size and the visual quality of the resulting image.

The research adopts a quantitative experimental methodology within the field of software engineering, aiming to develop an application capable of compressing digital images through the DCT technique. The evaluation focuses on assessing the effectiveness of the method in reducing file size without significantly compromising visual quality.

A key research question addressed in this study is: How can image file compression be effectively implemented using the DCT method? The implementation involves a compression process that transforms an original image file into a smaller-sized version while retaining as much of the original visual fidelity as possible.

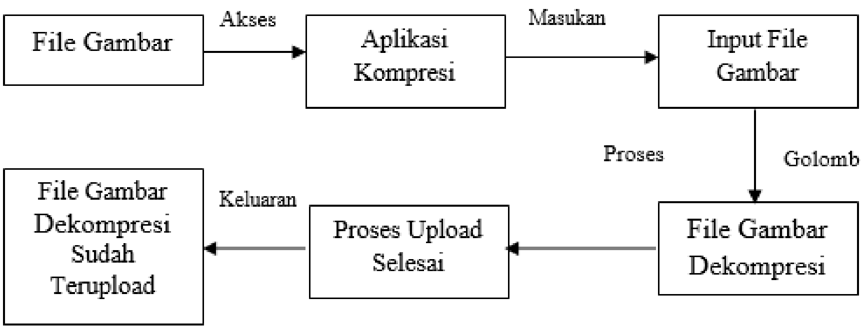

Figure 1. System Design Architecture for Image Decompression

If the image is in color (RGB), it must first be converted into a grayscale image so that only a single channel (pixel intensity) is processed. The grayscale pixels are then divided into **8×8** pixel blocks for further processing.

	0	1	2	3	4	5	6	7
0	52	55	61	66	70	61	64	73
1	63	59	66	90	109	85	69	72
2	62	59	68	113	144	104	66	73
3	63	58	71	122	154	106	70	69
4	67	61	68	104	126	88	68	70
5	79	65	60	70	77	68	85	75
6	85	71	64	59	55	61	65	83
7	87	79	69	68	65	76	78	94

The DCT works more efficiently on data with a zero mean; therefore, each value is reduced by 128. The Discrete Cosine Transform (DCT) is designed to perform optimally when its input values range from −128 to +127 (i.e., having a mean value of zero or close to zero), using the formula.

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Baris 1:

$f'(0,0) = 52 - 128 = -76$
$f'(0,1) = 55 - 128 = -73$
$f'(0,2) = 61 - 128 = -67$
$f'(0,3) = 66 - 128 = -62$
$f'(0,4) = 70 - 128 = -58$
$f'(0,5) = 61 - 128 = -67$
$f'(0,6) = 64 - 128 = -64$
$f'(0,7) = 73 - 128 = -55$

Baris 2:

$f'(1,0) = 63 - 128 = -65$
$f'(1,1) = 59 - 128 = -69$
$f'(1,2) = 66 - 128 = -62$
$f'(1,3) = 90 - 128 = -38$
$f'(1,4) = 109 - 128 = -19$
$f'(1,5) = 85 - 128 = -43$
$f'(1,6) = 69 - 128 = -59$
$f'(1,7) = 72 - 128 = -56$

Baris 3:

$f'(2,0) = 62 - 128 = -66$
$f'(2,1) = 59 - 128 = -69$
$f'(2,2) = 68 - 128 = -60$
$f'(2,3) = 113 - 128 = -15$
$f'(2,4) = 144 - 128 = 16$
$f'(2,5) = 104 - 128 = -24$
$f'(2,6) = 66 - 128 = -62$
$f'(2,7) = 73 - 128 = -55$

Baris 4:

$f'(3,0) = 63 - 128 = -65$
$f'(3,1) = 58 - 128 = -70$
$f'(3,2) = 71 - 128 = -57$
$f'(3,3) = 122 - 128 = -6$
$f'(3,4) = 154 - 128 = 26$
$f'(3,5) = 106 - 128 = -22$
$f'(3,6) = 70 - 128 = -58$
$f'(3,7) = 69 - 128 = -59$

Baris 5:

$f'(4,0) = 67 - 128 = -61$
$f'(4,1) = 61 - 128 = -67$
$f'(4,2) = 68 - 128 = -60$
$f'(4,3) = 104 - 128 = -24$
$f'(4,4) = 126 - 128 = -2$
$f'(4,5) = 88 - 128 = -40$
$f'(4,6) = 68 - 128 = -60$
$f'(4,7) = 70 - 128 = -58$

Baris 6:

$f'(5,0) = 79 - 128 = -49$
$f'(5,1) = 65 - 128 = -63$
$f'(5,2) = 60 - 128 = -68$
$f'(5,3) = 70 - 128 = -58$
$f'(5,4) = 77 - 128 = -51$
$f'(5,5) = 68 - 128 = -60$
$f'(5,6) = 58 - 128 = -70$
$f'(5,7) = 75 - 128 = -53$

Baris 7:

$f'(6,0) = 85 - 128 = -43$
$f'(6,1) = 71 - 128 = -57$
$f'(6,2) = 64 - 128 = -64$
$f'(6,3) = 59 - 128 = -69$
$f'(6,4) = 55 - 128 = -73$
$f'(6,5) = 61 - 128 = -67$
$f'(6,6) = 65 - 128 = -63$

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f'(6,7) = 83 − 128 = −45

Baris 8:

f'(7,0) = 87 − 128 = −41
f'(7,1) = 79 − 128 = −49
f'(7,2) = 69 − 128 = −59
f'(7,3) = 68 − 128 = −60
f'(7,4) = 65 − 128 = −63
f'(7,5) = 76 − 128 = −52
f'(7,6) = 78 − 128 = −50
f'(7,7) = 94 − 128 = −34

Final Block Result After Conversion (f'):

-76	-73	-67	-62	-58	-67	-64	-55
-65	-69	-62	-38	-19	-43	-59	-56
-66	-69	-60	-15	16	-24	-62	-55
-65	-70	-57	-6	26	-22	-58	-59
-61	-67	-60	-24	-2	-40	-60	-58
-49	-63	-68	-58	-51	-60	-70	-53
-43	-57	-64	-69	-73	-67	-63	-45
-41	-49	-59	-60	-63	-52	-50	-34

Use the formula: DCT 2D:

$$F(u,v) = \frac{1}{4} \cdot C(u) \cdot C(v) \cdot \sum_{x=0}^{7} \sum_{y=0}^{7} f(x,y) \cdot \cos\left[\frac{(2x+1)u\pi}{16}\right] \cdot \cos\left[\frac{(2y+1)v\pi}{16}\right]$$

With:

The result is the DCT coefficient matrix of the 8×8 block (values rounded):

	u=0	**u=1**	**u=2**	**u=3**	**u=4**	**u=5**	**u=6**	**u=7**
v=0	-415	-30	-61	27	56	-20	-2	0
v=1	-22	-61	-32	10	13	-7	-8	4
v=2	-58	-10	10	-15	-9	7	1	2
v=3	-40	10	20	-3	-1	1	2	0
v=4	-12	-7	-13	-1	-2	1	0	0
v=5	-7	-3	-2	3	1	0	0	0
v=6	-1	0	0	1	0	0	0	0
v=7	0	0	1	2	0	1	0	0

After obtaining the DCT matrix, quantization is performed by dividing each element of the matrix by the corresponding element in the standard quantization matrix, followed by rounding.

This chapter presents the results of the implementation and testing of the image compression application using the Discrete Cosine Transform (DCT) method, along with a discussion on its effectiveness and the quality of the compression results. The developed application features a simple and user-friendly interface, allowing users to select an image file, specify the compression level (quality factor), and directly compare the original image with the compressed version.

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The test results show that the application is capable of significantly reducing image file size with a relatively high compression ratio. The compression process involves dividing the image into pixel blocks, applying the DCT transformation, and then quantizing the frequency coefficients. After compression, the application also calculates the Peak Signal-to-Noise Ratio (PSNR) to measure the visual quality of the compressed image. A higher PSNR value indicates better quality of the compressed image compared to the original.

The discussion of the results indicates that the DCT method is quite effective for image compression, particularly at medium to high quality factor settings. The file size reduction does not result in a significant decrease in quality, meaning the compressed image remains visually clear and acceptable. In addition, the application operates fairly quickly for medium-resolution images, although computation time increases for high-resolution images.

The dashboard page display can be seen as follows:

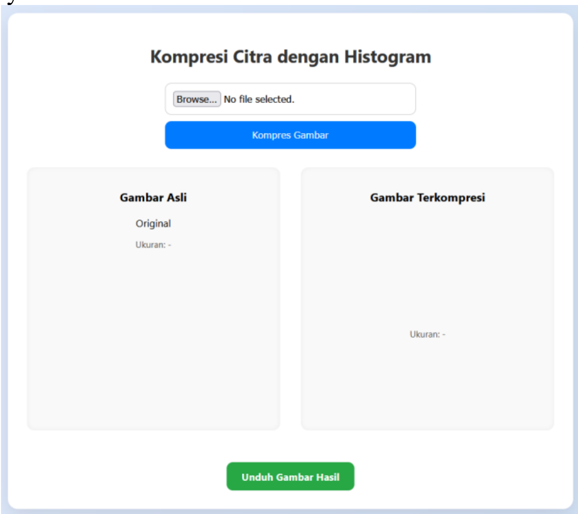

Figure 2. Dashboard

On this page, users can access various core features of the system, including selecting the image file to be processed, setting the desired compression quality level, and viewing detailed information on file sizes before and after the compression process. In addition, the dashboard visually displays the compressed image side by side with the original image, making it easier for users to compare quality and ensure that the compression results meet their expectations.

The image input page display can be seen as follows:

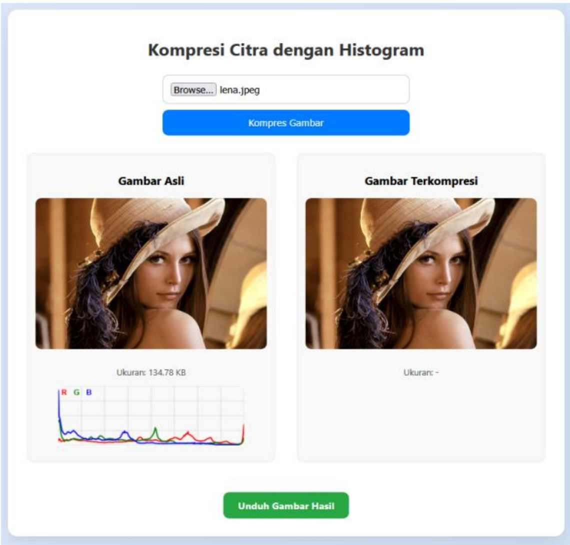

Figure 3. Input Image

The image input page in the image compression application using the Discrete Cosine Transform (DCT) method. On this page, users can select or upload an image file from their storage device for further processing.

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The image compression page display can be seen as follows:

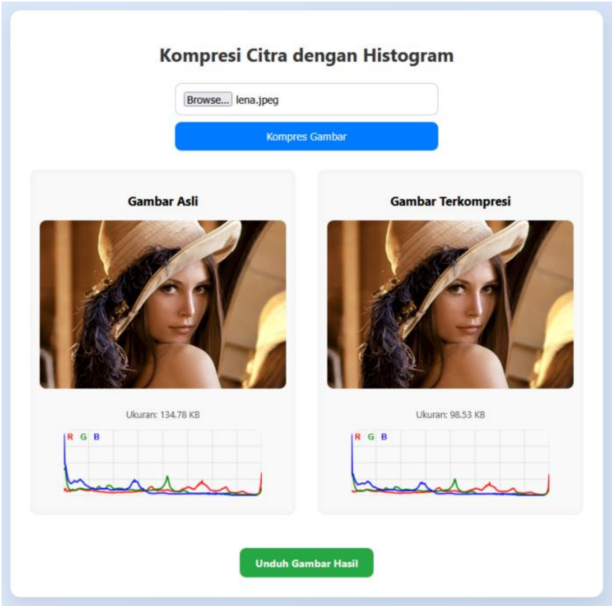

Figure 4. Prosesing Kompresi Image

The image compression page in the compression application uses the Discrete Cosine Transform (DCT) method. On this page, users can adjust the compression level or image quality by selecting the available quality factor values.

4. CONCLUSION

Based on the results of the tests conducted, it can be concluded that the image compression application using the Discrete Cosine Transform (DCT) method has achieved the following:

1. The application successfully implemented the Discrete Cosine Transform (DCT) method to compress images effectively, achieving significant reductions in file size.
2. The quality of the compressed images was maintained, as indicated by PSNR values that remained within a good category and visual appearances that were not significantly different from the original images.
3. The application interface is user-friendly, enabling users to easily upload, compress, and download the compressed images.

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