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Image Data Compression Using Discrete Cosine Transform Technique for Wireless Transmission

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ABSTRACT

Telemetry data transfer over long-range wireless network for internet of things-based applications presently gaining popularity and this trend continuous in the era of Industrial Revolution (IR 4.0). However, transmitting larger amount of data such as images is a challenging task and requires further attention and research. Moreover, transmitting data over open agricultural area requires this capability to collect field data for further research and analysis. This work aims to propose a suitable image compression technique and recommends for the best compression ratio as to address the aforementioned issue. Discrete Cosine Transform (DCT) is a well-known lossy-based image compression technique, which has been explored along with another compression algorithm known as Fast Fourier Transform (FFT). Comparison between the two most widely used compression algorithms was analyzed and discussed. In this paper, golden apple snail images are acquired from various databases which include the mature snail, adult female laying eggs, snail pink eggs on stem and snails in the water. A MATLAB code is written to implement both algorithms with input images from the database is tested on the developed algorithm. Simulation results have shown that the input images can be compressed with a different value of compression ratio (CR) ranging from 3.00 to 50.00. Other than that, it is noted that the quality of the compression ratio is 49.04 with Mean Square Error (MSE) of 172.72 and Peak Signal to Noise Ratio (PSNR) of 25.75.

Keywords: Long-range network, Discrete Cosine Transform, Fast Fourier Transform, Compression technique, Wireless Sensor Network.

1. INTRODUCTION

Digital images consist of large amounts of information that require greater bandwidth. Image compression techniques can generally be categorized into two types, namely lossy and lossless [8]. In lossy images compression there are losing some of data information during the process and the data image is irreversible to its original image, but in lossless images compression the output images are almost the same as input and its reversible. Transmitting a large amount of data images via wireless remote sensing (WSN) in agricultural environment is a bit challenging. The time spending over a long-range communication is increased while a data cannot be sent simultaneously in rural area especially in paddy field while the crops need to be monitored regularly. Data images of paddy attacked by snails which are highly invasive and cause damage to rice crops must be transmit in a small size and need to divide into a chunk of data packet. It is because due to the limited data rate and payload size, LoRa takes at least 498 seconds to transmit a 1MB images, using its peak physical layer data rate [9]. There are so many wireless communication technologies that can be used for images data transmission such as Bluetooth, Wi-Fi, WiMAX, Zigbee, LTE, LoRa and LoRaWan. Some of them have their own advantages and limitations.

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But the main concentration is over compression and decompression of scaling down the images which can be carried out over LoRaWan network. The use of digital products such as cameras, transfer and storage media has also increased in this new era. Image files can be of larger and consume a lot of memory [8]. Any grayscale image measuring 256 x 256 will have about 65,536 elements to store while a 640 x 480 color image will have about one million. This will cause a big problem for transmitting data images over a long-range network.

2. LORA FEATURES AND LIMITATION TO IMAGE TRANSMISSION

Long range wireless area network (LoRa) enables wireless sensor nodes to provide more strength signal in data transmission over longer range data transmission (typically between 8-13 km). However, transferring multimedia data over LoRa is a quite difficult because of limitation of data transmission. This is because WSN consists of remote sensing nodes monitoring which send collected data to a sink central processing for a specific application. The biggest problem is the energy consumption in WSN which should be reduced to offer a long-range connection. In the other aspect, transferring data from sensor nodes is obstructed by the narrow bandwidth of this network and their limited memory for computational process [1]. For instance, the maximum duty-cycle of LoRa is constrained to one percent and it results in a maximum transmission time of 36 sec/hour in each sub-band for each end-device. This limitation makes transferring data from devices like image sensors complicated, thus wireless data transfer especially for multimedia data requires proper data compression technique before transmission

In last two decades, images compression methods have been deployed to face a digital imaging challenge. These compression techniques can be categorized into two type, lossy and lossless compression. There are many approaches can be implemented to archive these two types of compressions. Some of them are Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), Fractal Compression, Huffman Encoding, and Lempel-Ziv-Welch Coding [5].

2.1 Lossy Compression Method

Lossy compression method is an images compression technique that apply a transformation process in changing the raw input data images into a new output data image called as constructed images. The constructed images in lossy compression will carried a losing some information of the original data but the size and quality of the images is reduced because of the compression rate has been applied [6]. This method is among of the best approaches used by most of researcher for wireless images data transfer over long-range network [1-3, 9].

2.2 Lossless Compression Method

This technique is a wavelet method which means the output images are almost the same as input images. This method is very useful when the output images represent details information where every information of each pixel become very important [5]. It is very useful in processing medical imaging while every data in those images not losing much information. This method remain low compression rate compared to lossy compression technique and its commonly used by researcher in medical images purpose. Discrete Wavelet Transform (DWT) is widely used in this method [7]. The comparison between four examples of image compression technique can be explained in the Table 1.

Table 1 Comparison between four examples of image compression techniques.

	DISCRETE COSINE TRANSFORM [6]	**FRACTAL COMPRESSION** [5]	**HUFFMAN ENCODING** [4]	**LZW CODING** [5]
Compression	Lossy		Lossless	
Quality	Losing some information		Output almost the same as input	
Properties	Large compression gains. High compression rate. Very small the signal to noise ratio. Not guarantee that critical features will not be lost.		Identical to the original image. Low compression rate. The compression scheme discards redundant information. Contains degradation relative to the original.	
Method	Using cosine functions transform.	Square block called as Parent Blocks.	Using a binary tree.	A dictionary-based coding.
Image Format	Joint Photographic Expert Group (JPEG), Joint Photographic Experts Group 2000 (JPEG 2000)		Bitmap (BMP), Portable Network Graphic (PNG), Tagged Image File Format (TIFF)	
Advantages	Can generate much smaller compressed file. Image quality is mostly retained.		Retain full quality of images. Can restore compressed data.	
Disadvantages	File cannot be restored. The more the file is compressed, the higher the risk of perceptible differences.		Smallest reduction in file size. Yields the worst compression results.	

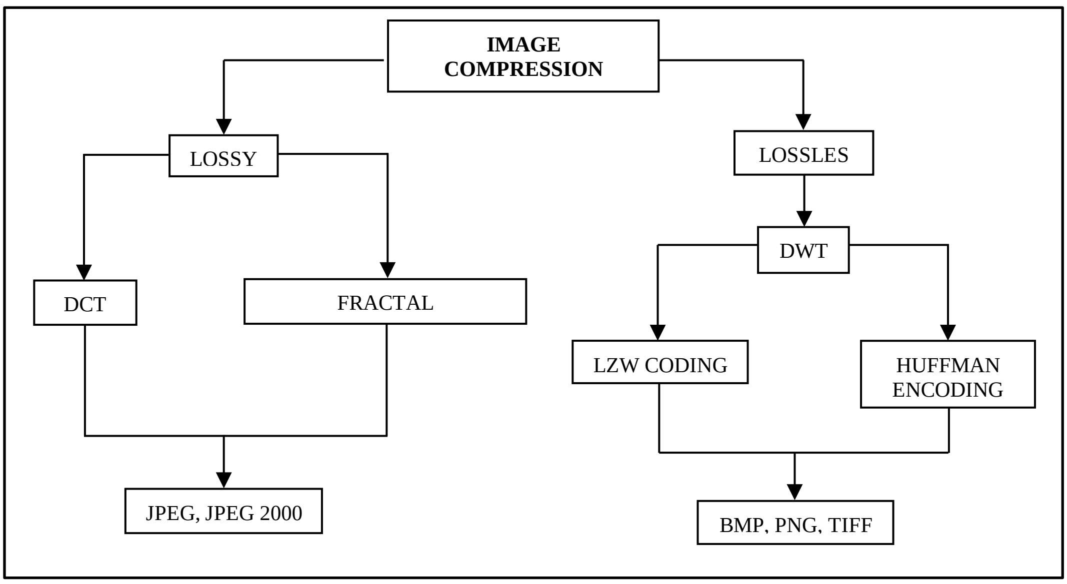


Figure 1. Block diagram of image compression by categories.

3. PROPOSED METHOD

To get the best image compression, an algorithm called Fast Fourier Transform (FFT) will be applied to image of golden apple snail. Fast Fourier Transform (FFT) is the algorithm for calculating discrete value of DFT. Discrete Fourier Transform (DFT) is a method for transforming time domain into frequency domain. FFT is a Fourier transform developed from Discrete Fourier Transform (DFT) algorithm. With the FFT method, the computational rate of the Fourier transformation calculations can be increased. DFT computation takes time to process loops and requires a lot of memory.

By applying the FFT algorithm, the DFT calculation can be shortened, in this case the looping process can be reduced. FFT is divided into two namely DIT (Decimation in Time) and DIF (Decimation in Frequency) method, and both have the same function that is to transform the signal into its fundamental frequency. Decimation is the process of dividing the signal into smaller parts that are aimed for get faster processing time where the frequency components are dividing into even and odd parts. If the input signal at the time domain of N-points is x (n), the initial step is to separate into 2 equal parts (N/2 points). It utilizes the FFT structure for speedy computation of DCT, hence suitable for large input images. In MATLAB, it is achieved by using dct2() function. For example, in Figure 2 if the 8 x 8 image segment is used, it also can have the DCT coefficients by using dct2() function in every block of pixels. In Figure 3, at the top left corner of the coefficients is the DC component which carried the largest DCT coefficients, and the rest of the component are smaller values if compared to the top left one. That means it can achieve the image compression by simply making the small coefficients to 0 value. This is called a quantization process in Figure 4.

$$
\begin{bmatrix}
45 & 18 & 47 & 41 & 14 & 11 & 37 & 32 \\
13 & 11 & 43 & 12 & 26 & 8 & 10 & 15 \\
20 & 19 & 31 & 39 & 17 & 12 & 34 & 47 \\
27 & 15 & 28 & 33 & 5 & 17 & 27 & 35 \\
45 & 34 & 26 & 19 & 2 & 49 & 39 & 21 \\
13 & 7 & 1 & 46 & 4 & 21 & 22 & 17 \\
40 & 8 & 12 & 41 & 40 & 28 & 38 & 13 \\
47 & 43 & 5 & 26 & 1 & 2 & 6 & 11
\end{bmatrix}
$$

Figure 2. 8 x 8 Image segment

$$
\begin{bmatrix}
189.3750 & 11.2625 & 14.2389 & -11.7633 & 12.1250 & 39.3032 & 0.7317 & -11.4883 \\
13.0005 & -9.0938 & -2.5408 & -34.7074 & -7.2808 & -0.7041 & 18.5921 & 27.2826 \\
-5.1750 & 25.9718 & -3.8029 & -0.9106 & 14.8950 & -3.1129 & -8.3295 & 15.2390 \\
7.4729 & -8.1367 & -9.8750 & 15.0937 & -6.32370 & 17.6210 & 4.7798 & -4.7374 \\
12.3750 & 23.6339 & 30.5381 & 2.1903 & -12.3750 & 3.7889 & 4.8043 & -10.2701 \\
20.5578 & -16.2111 & -7.0980 & -3.7616 & 19.3353 & 18.7785 & -5.6627 & 4.50970 \\
-3.6743 & -3.2712 & 9.9205 & -19.1920 & 8.8485 & 6.8259 & -10.697 & -21.4293 \\
32.7236 & -2.6000 & 9.6278 & 14.0576 & -8.3389 & 3.7411 & 0.0111 & 3.7216
\end{bmatrix}
$$

Figure 3. DCT coefficients

$$
\begin{bmatrix}
189.3750 & 11.2625 & 14.2389 & 0.0000 & 12.1250 & 39.3032 & 0.0000 & 0.0000 \\
13.0005 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 18.5921 & 27.2826 \\
0.0000 & 25.9718 & 0.0000 & 0.0000 & 14.8950 & 0.0000 & 0.0000 & 15.2390 \\
0.0000 & 0.0000 & 0.0000 & 15.0937 & 0.0000 & 17.6210 & 0.0000 & 0.0000 \\
12.3750 & 23.6339 & 30.5381 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
20.5578 & 0.0000 & 0.0000 & 0.0000 & 19.3353 & 18.7785 & 0.0000 & 0.0000 \\
0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 & 0.0000 \\
32.7236 & 0.0000 & 0.0000 & 14.0576 & 0.0000 & 0.0000 & 0.0000 & 0.0000
\end{bmatrix}
$$

Figure 4. Quantization process of DCT coefficients

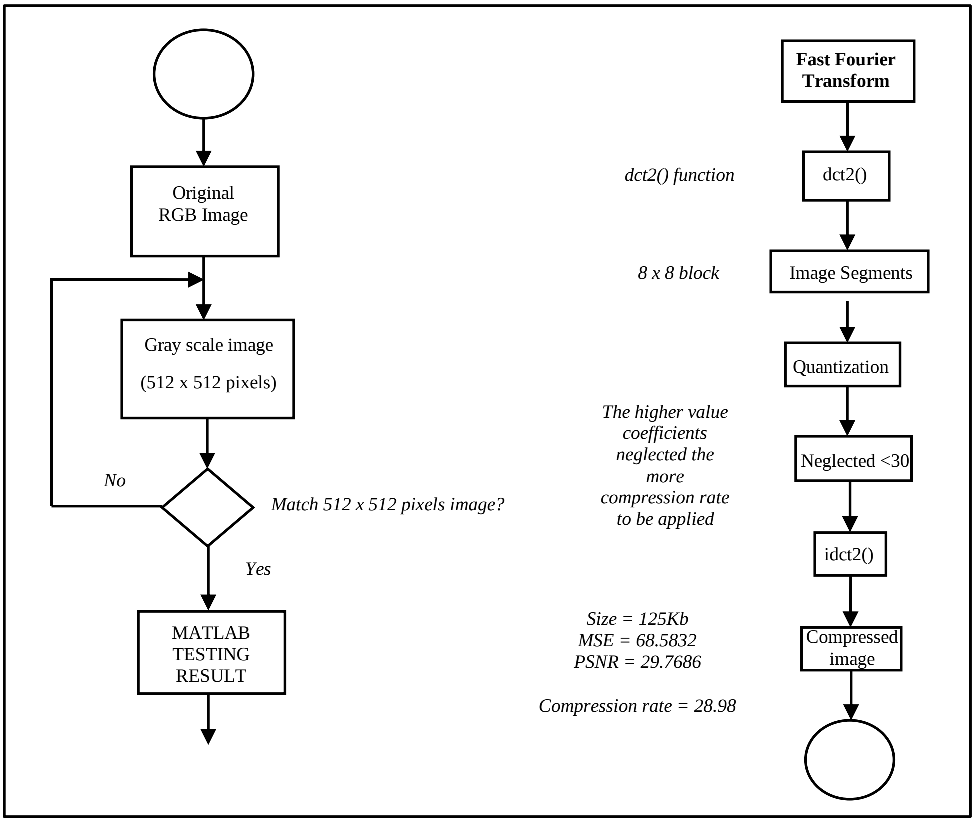


Figure 5. Flowchart of Fast Fourier Transform (FFT) based approach.

4. RESULTS AND DISCUSSION

By using the Fast Fourier Transform (FFT) in MATLAB, a grayscale of 512 x 512 pixels image in size 176 KB can be scaled down as in the Figure 5. The image of the golden apple snails still can be seen clearly by using this technique since the truncation has been set <30 to neglect the coefficients to 0. From this technique the output images can be obtained by varying the truncation coefficients value to get the smaller image of any sizes. FFT algorithm can be set to multiple values. The value of coefficients truncation has been set below than 10, 30, 50, 70 and 90 of the coefficients. The highest compression has been applied with the truncation value <90 and the multiple truncation value are shown in the Table 2.

Table 2 Multiple truncation coefficients value for FFT based result.

	Fast Fourier Transform (FFT) *(Coefficient's truncation value)* < 10	< 30	< 50	< 70	< 90
Original image (KB)	176 KB	176 KB	176 KB	176 KB	176 KB
Compressed image size (KB)	170 KB	125 KB	106 KB	96.8 KB	89.7 KB
Compression Ratio (CR)	3.41	28.98	39.77	45.00	49.04
Mean Square Error (MSE)	14.89	68.58	110.27	143.98	172.72
Peak Signal to Noise Ratio (PSNR)	36.40	29.77	27.71	26.54	25.75
Original image (512 x 512 pixels)					
Output image (512 x 512 pixels)					

Table 3 Comparison against previous work on image compression.

Paper	Method	MSE	PSNR	Compression Ratio
[10]	DWT-DCT-SVD	23.07	34.50	46.91
	DCT-SVD	18.01	35.58	44.74
	DCT	14.25	36.59	38.13
[11]	Quantization Smoothing(a)	-	29.12	34.66
	Quantization Smoothing(b)	-	31.47	21.81
This work	FFT(a)	14.89	36.40	3.41
	FFT(b)	68.58	29.77	28.98
	FFT(c)	110.27	27.71	39.77
	FFT(d)	143.98	26.54	45.00
	FFT(e)	172.72	25.75	49.04

To assess the quality of an images which transmitted over a network, the peak signal-to-noise ratio (PSNR) will be used. This assessment is based on the measurement of differences between the pixels of reconstructed image and the original image.

The PSNR of image transmission can be calculated in equation 1.

$$PSNR = 10\log\frac{S^2}{MSE} \quad (1)$$

Where, for an 8-bit images, S is equal to 255 and MSE is the mean square error which is the average of the squared difference in the intensity pixels in the original image and the output image. This can be calculated in equation 2.

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2 \quad (2)$$

Where m and n are the respective length and width of the image in pixels I(i,j) and K(i,j) are functions describing the intensity of individual pixels in the transmitted and received image respectively.

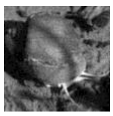
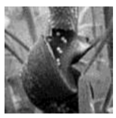
The compression ratio of image can be calculated in equation 3.

$$CR = \frac{n_2}{n_1} \quad (3)$$

Where n_1 is the number of bits of original image, and n_2 is the number of bits of compressed image.

From Table 3, there have five different compression techniques by the previous work on lossy image compression. Paper [10] has proposed three different lossy compression algorithms on one single image where the size used is 425 x 318 pixels. In the experiment, DCT method is the lowest compression ratio with 38.13 and the Mean Square Error (MSE) is 14.25 which is the lowest among the other methods. These three methods were using multiple threshold value in their proposed technique. Paper [11] has proposed a quantization-smoothing where there have two different image (a) and (b). The image (a) is a photo of baboon, and (b) is a photo of cameraman. Both photos were applied with different value of quantization-smoothing factor. The compressed image (a) has the higher compression ratio, 34.66 and gives lower PSNR value, 29.12. The size of block images has been used in the proposed method is 4x4. In this work, the pixel images 8x8 has been used, while the original size is 176 KB has been compressed with five different values of truncation using FFT algorithm. As a result, truncation value (e) gains the highest compression ratio, but the PSNR is very low among others. The image of golden apple snails can be seen clearly although the peak signal to noise ratio is low. In this FFT proposed method, the higher truncation value is applied, the more compression ratio will be gained. As the conclusion, the value of (e) will be used to transmit over a long-range wireless network because of the size of image has been reduced to 89.7 KB which is the smallest among the others.

Table 4 Comparison result based on parameters by five samples image.

	FFT Truncation Value (<90)				
	Sample01	*Sample02*	*Sample03*	*Sample04*	*Sample05*
Original image (KB)	132 KB	138 KB	141 KB	133 KB	127 KB
Compressed image size (KB)	91.5 KB	87 KB	84.9 KB	100 KB	82.5 KB
Compression Ratio (CR)	30.68	36.96	39.79	24.81	35.04
Mean Square Error (MSE)	129.4014	128.3558	142.7150	189.9646	150.7336
Peak Signal to Noise Ratio (PSNR)	27.0114	27.0466	26.5861	25.3441	26.3487
Original image (512 x 512 pixels)					
Output image (512 x 512 pixels)					

Result from Table 4 shown five different images that has been used to measure the parameters in term of Compression Ratio (CR), Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR). In addition, the images size was also obtained by using a single truncation coefficient value that has been selected which is <90. The truncation value <90 was used in the FFT algorithm because this is the value which gained the most compression ratio from the previous experiment. By applying FFT on five different images, it shows the higher compression ratio gained is on image *Sample03* the lowest is on image *Sample04* with value 39.79 and 24.81. That means, the result in the Table 4 do not achieve the higher compression gained as compared to the Table 2. The pixels of all five different images are using the same as the previous experiment which is 512 x 512 pixels. If the truncation value <90 has been applied to any images with the same pixels, the results can be analysis by looking at the main objective of the study which is to get the highest compression ratio that mean the size can be reduced as much as possible. It concludes that the highest compression gained in this work are referred to the result in Table 2, which is 49.04 with the truncation coefficient value set to <90. Although the size of six different images is the same with 512 x 512 pixels and the truncation value was set to <90 to all images, the compression ratio is based on the images its selves. Some of the images contain high frequency values, some do not. That is why the compression ratios obtained are not too much different from each other.

Table 5 shows the compression ratio results between all images that has been used in this work by using FFT based algorithm with the truncation set to value <90.

Table 5 Result of sample images by its compression ratio gained using FFT algorithm.

Sample Image	Original Size (KB)	Compressed Size (KB)	Compression Ratio (CR)
Sample01	132 KB	91.5 KB	30.68
Sample02	138 KB	87 KB	36.96
Sample03	141 KB	84.9 KB	39.79
Sample04	133 KB	100 KB	24.81
Sample05	127 KB	82.5 KB	35.04
FFT (e)	176 KB	89.7 KB	49.04

5. CONCLUSION

In this work, the image compression of golden apple snails has been used to identify whether the best compression algorithm has chosen appropriately. By applying the lossy image compression on a sample image, the compression ratio, MSE and PSNR has been obtained by using the FFT algorithm written in MATLAB software. As a result, there are some parameters need to consider achieving the main objective of this work to transmit the output image over a long-range wireless network. FFT algorithm is the best method to choose with the compression ratio at 49.04, MSE 172.72 and PSNR 25.75. Although better compression ratios are achieved, the trade-off is in a reconstructed image which is not identical to the original image in the sense of individual pixel values. However, the information presented may still appear to be visually identical. In fact, herein is the key to achieve higher compression ratios in lossy compression techniques. Its objective is to take any means to reduce the amount of data needed to represent a certain amount of visual information. Its emphasis, however, is not on the exactness of the pixel values but rather on the exactness of the visual quality of the reconstructed image of the golden apple snails. The further work can be done by gather all results from the previous experiments. The focus is to transmit the image data with very small size but compatible with LoRa device module which has been proposed. All the parameters need to be study to match with the Wireless Sensor Network (WSN) LoRa Semtech SX1211 Module.

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