New Trend in using the JPEG compression for the images used in media

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Abstract
A few methods established to store, transmit, receive and demonstrate images. One of these ways is the JPEG format which is considered a lossy format for compressing the images. This format depends on removing the high frequencies (details) from the image that cannot be detected by the human eye before storing the image.

Keywords
JPEG- Discreate cosine transform- DCT2- PSNR- Peak signal-to-noise ratio- SSIM- Structural Similarity Index- Spatial Frequency.

الملخص
من الناحية الفنية هناك طرق عديدة لتخزين الصور، ونقلها، واستقبالها وعرضها. إحدى هذه الطرق هي تنسيق JPEG الذي يعتبر تنسيقًا لضغط الصور. يعتمد هذا التنسيق على إزالة الترددات (التفاصيل) العالية من الصورة والتي لا يمكن للعين البشرية اكتشافها قبل تخزين الصورة.

الكلمات المفتاحية
JPEG- Discreate cosine transform- DCT2- PSNR- ذروة نسبة الإشارة إلى الضوضاء -SSIM - مؤشر التشابه الهيكلي - التردد المكاني.

Introduction
Data compression is, in the context of computer science, the science (and art) of representing information in a compact form. It has been one of the critical
enabling technologies for the ongoing digital multimedia revolution for decades. (Pu, 2006). Image Compression, the art and science of reducing the amount of data required to represent an image, is one of the most useful and commercially successful technologies in the field of digital image processing (Conzalez & Woods, 2008). Two characteristics of image data are of quantity and quality: The first characteristic of images is the massive amount of data involved in almost every application (Pu, 2006). The second characteristic of images is that the quality of an image depends not only on the image data but also on the display device and the sensation of the human visual system (Pu, 2006). JPEG compression (Joint Photograph Expert Group) standard

for images of photographic quality. It is lossy baseline coding system uses quantized discrete cosine transform (DCT) on 8X8 image blocks (Conzalez & Woods, 2008). The JPEG compression procedures pass by three main steps: 1) the transforming of the image to its 2-D DCT transformation, 2) quantization (rounding any floating-point number after transformation to an integer number), 3) coding (converting decimal numbers to a binary numbers) (Agoltini, et al., 2001). The following figure summarizes these steps:

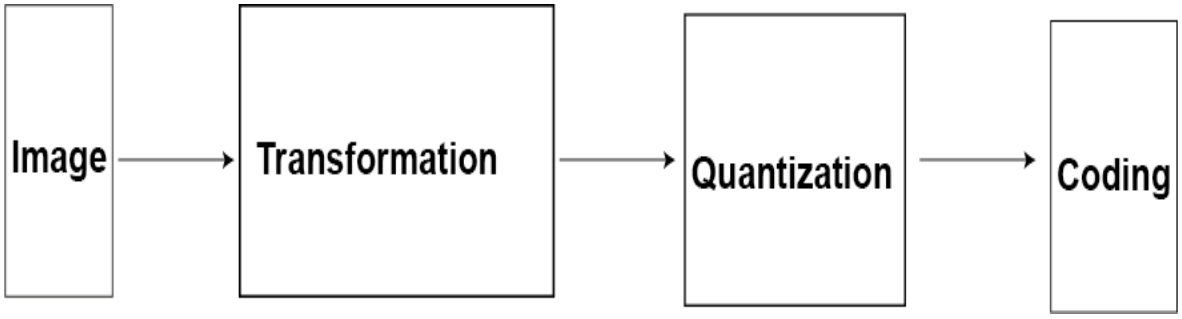


Figure 1 Steps of JPEG compression

This research will apply the basic trigonometric functions (sin, cos) to the image prior taking the JPEG compression steps and analyze the results of this action before and after applying each function. There will be no use of any other trigonometry functions in this research as these functions (csc, sec, cot…etc.). The research is going to focus on the true color images.

Statement of the problem:

Questions have been raised about the need to increase the image rate of compression with the minimal loss of information and quality of the image when used in media production.

Hypothesis:

The hypothesis that will be tested is that the amount of data loss in the image after applying the trigonometric functions is not affecting the quality of the image while the image size on the saving media is less.

Objective:

The objective of this research is to reduce the amount of data storage of the image on the saving media by applying the trigonometric functions on the image prior the JPEG compression and restore the image with minimal data loss.

Significance:

This study aims to contribute to an important role helping in saving the storage media space, more over helping during the transmission and receiving the image data by any means of communication technology.

Terminologies:

For this study, there are symbols describing the images used as in table number 1

Table 1 images used symbols

Symbol	Image
s	Original image in tiff format
k	Original image after converting to JPEG
j	Original image after applying cos function
js	Original image after applying sin function
dB	Decibel

The name of the images throughout the study will be as follows:

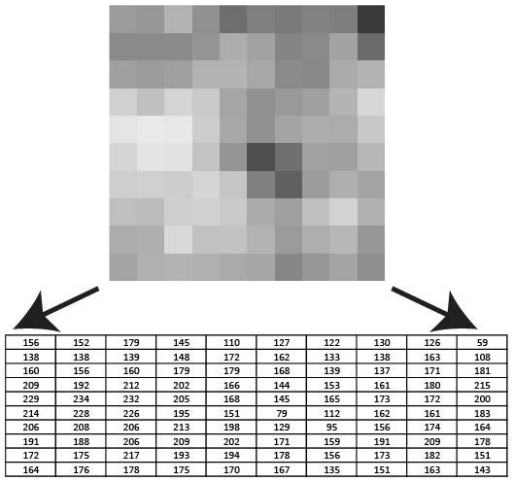
Symbol_Quality Value_i i =1…. N and N is the number of images

Quality Value = 25 or 50 or 75 or 100

Literature review:

Image representation

An image may be defined as a two dimensional function, f(x, y), where x and y are spatial (plan) coordinates and amplitude of, f at any pair of coordinates (x, y) is called the intensity or gray levels of the image at that point (Conzalez & Woods, 2008). For the true color image, the image function will be f (x, y, 3) where 3 denotes that there are 3 Matrices for each spectral primary colors (Red, Green, Blue). The following figure shows the image representation on computer. The intensity levels are between 0 and 255 for each pixel in the image, where 0 represents total black and 255 is total white while the other numbers are the shades in-between. (McAndrew;, 2004)



156	152	179	145	110	127	122	130	126	59
138	138	139	148	172	162	133	138	163	108
160	156	160	179	179	168	139	137	171	181
209	192	212	202	166	144	153	161	180	215
229	234	232	205	168	145	165	173	172	200
214	228	226	195	151	79	112	162	161	183
206	208	206	213	198	129	95	156	174	164
191	188	206	209	202	171	159	191	209	178
172	175	217	193	194	178	156	173	182	151
164	176	178	175	170	167	135	151	163	143

Figure 2: Representation of an image in computer using the uint8 (unsigned integer)

Trigonometric Function

Sine and cosine functions relate real number values to the x- and y-coordinates of a point on the unit circle. These functions will be explained as being used in Matlab program as it is the program used in this study to hold the experiments.

Sine function

There are two types of sin functions in Matlab, and they are (sin) and (sind). Sin, measure the sine of argument in radians. While (sind) measures the sine of argument in degrees (The MathWorks, Inc., 1994-2024). The (sin) and (sind) functions can include the real numbers from

-1 to 1 and what is more than 1 and less than -1 defined as an imaginary number. I am going to use both functions in my test.

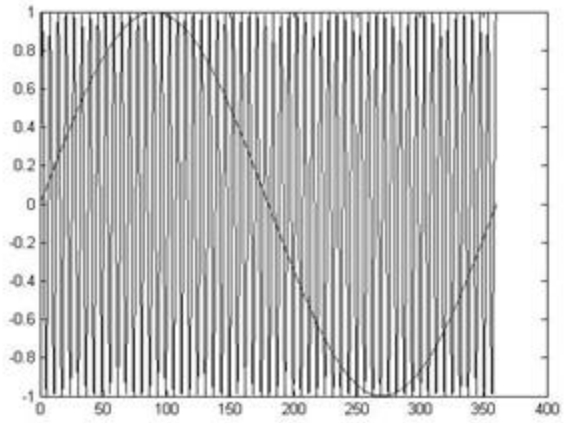


Figure 3 clarifies the difference between the actions of function sin (blue line) and sind (red line)

For the (sin) function the values of the main angles (0, 90, 180 270, 360) are as follows (0, 0.8940, -0.8012, -0.1760, 0.9589) respectively.

While the values of the angles between 0 and 1 are 0 and 0.8415 respectively.

On the other hand the function (sind) for any angles between 0 and 90, the sind function takes the values between 0 and 1, and the angles more than 90 the value returns back in a decreasing order till it reaches to 0 on angle 180 then goes to the negative part for value greater than 180 till it reaches (-1) on the angle 270 then increases back and continues to increase till it reaches 0 on the angle 360. And since our image values between 0 and 255 so the sind values will fluctuates between 0 and (-0.9659). On the other hand, the values between 0 and 1 which are the values of gray levels of an image in the double precision real number format can take the values between 0 and 0.0175.

The following graph in figure 4 illustrates these relations.

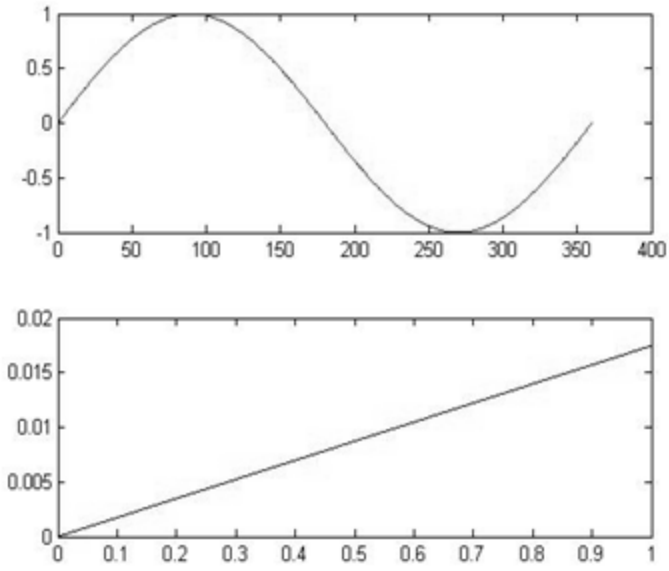


Figure 4 shows sine function for values from 0 to 360 degrees (up) and for the values from 0 to 1 degree (down).

Cosine function (cos)

The same for cosine function, there are two types of cosine functions in Matlab, (cos) and (cosd). Cos, measure the sine of argument in radians. While (Cosd) measures the cosine of argument in degrees (The MathWorks, 1994-2024).

The same as sine function, the (cos) and (cosd) functions; their values are between 1 and -1, what is more than 1 and less than -1 are defined as imaginary values.

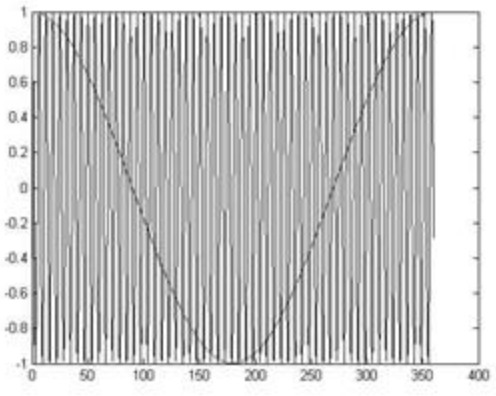


Figure 5 shows the difference between the actions of function cos (blue line) and cosd (red line)

The cosine function is the same as the sine function but with a lag 90 degrees.

$$\sin(\theta) = \cos(\frac{\pi}{2} - \theta)$$

Equation 1

For the (cos) function the values of the main angles (0, 90, 180 270, 360) are as follows (1, 0.4481, -0.5985, 0.9844, -0.2837) respectively.

While the (cosd) function to the value of 0 the (cosd) function will be 1 and when the value is 90 the (cosd) function will be equal to 0 till the angle reaches 180 degrees the (cosd) function will equal to -1. Then the (cosd) function will go back and increase till it reaches 0 on the angle 270 degrees and continues increasing till it reaches the value 1 on the 360 degrees. While on the double precision real number format the values will be 1 and 0.9998. The illustration on figure 6 shows this relation.

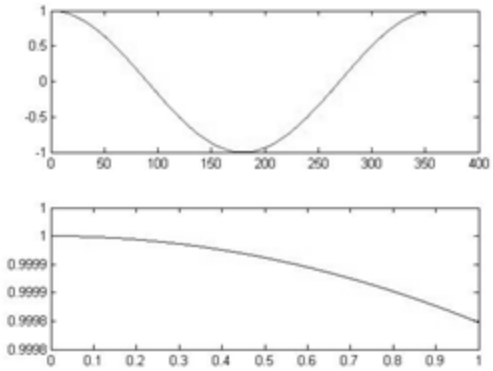


Figure 6 shows cosine function for values from 0 to 360 degrees (upper) and for value from 0 to 1 degree (lower).

Discrete Cosine Transform (DCT):

A periodic function can be represented as the sum of sines and cosines. This fact was discovered by the French mathematician and physicist Jean Baptiste Joseph Fourier (1768-1830) and the work was published in 1822. DCT was included in JPEG and MPEG in the years prior to JPEG 2000 where wavelet transform methods are included (Pu, 2006).

Peak Signal to Nosie Ratio (PSNR):

Peak-signal-to-noise-ratio (PSNR) matrix (this measures the error relative to the average squared value of the signal, again normally in logarithmic scale (dB)) (Pu, 2006).

Program used in the experiment

The Matlab program will be used during this study; it is a program used by millions of engineers and scientists worldwide to analyze and design the systems and products transforming our world. It is used for signal processing, image processing (MathWorks, 1994-2024) which is important for doing the experiment, comparing and analyzing the results.

JPEG format in Matlab

The Matlab stands for (MATrixLABoratory) (Tiwari, Mishra, Bhatia, & Yadav, 2013) is a mathematical program used for many applications, one of these applications is the image processing. The Matlab supports the saving of images using JPEG format. In this research the saving function called 'imwrite' and a parameter called 'Quality' used in this function, which is a value between 0 and 100, the higher the number the higher the quality (MathWorks, 2000). This research will not be using the hundred degrees of quality but uses four degrees of quality (25, 50, 75, and 100).

Methodology:

The research employes the experimental and quantitative method using the equation (2&3) to study the problem, achieve the research hypothesis, and demonstrate its significance.

$$\sin(s_i) = \mathrm{j}s_i$$

Equation 2

$$\cos(\mathrm{s}_i) = \mathrm{j}_i$$

Equation 3

Where I =1…N, and N is the number of image samples.

Choosing the sample of Experiment:

The characteristics of the sample image used for the experiment are downloaded from the site (https://www.signatureedits.com/free-raw-photos/) will be as Follows:

The samples must be of (raw format) the convert to tiff format.

True color image, i.e. a RGB color mode image.

The sample images have the same resolution (300 ppi).

Most of the grade levels should be covered in the images, i.e. it should contain most of the in between levels from 0 which is totally black to 255 (uint8 format) or 1 (double precision real number format) which is totally white.

The sample should have a raw image format. and to be converted to a tiff format.

The samples are shown in figure 7:

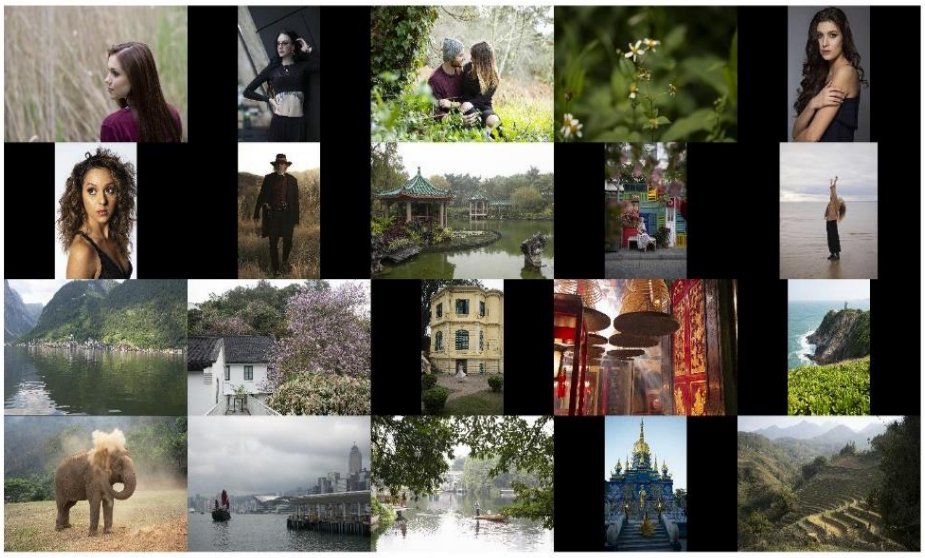


Figure 7: The original samples of images

The size of the sample images on the hard drive measured in bytes as follows in table 2.

Table 2 shows the saving sizes of the original samples images on hard drive measured in bytes

Original Image	Original Image Size
s1.tif'	108493888
s2.tif'	90351996
s3.tif'	66396724
s4.tif'	72023342
s5.tif'	59922004
s6.tif'	108495924
s7.tif'	84018272
s8.tif'	59913366
s9.tif'	72029790
s10.tif'	26488916
s11.tif'	36673472
s12.tif'	59919676
s13.tif'	72031614
s14.tif'	59919478
s15.tif'	59919870
s16.tif'	72026542
s17.tif'	59907810
s18.tif'	59921656
s19.tif'	98252824
s20.tif'	72027640

Procedure

The following procedure will be followed to accomplish the experiment that will study the problem, achieve the research hypothesis, and demonstrate its significance.

First phase

Import the original sample images in tiff format (si), Where i=1…N, and N is the number of image samples in Matlab script.

Convert the original sample images to double,

Save the original images to JPEG format (ki.jpg) with different quality level (25,50, 75, and 100).

Apply the (sin, cos) function on the sample images for different quality levels (25,50, 75, and 100).

Save the images of applied function (sin, cos) to JPEG format (jsi.jpg, ji.jpg) respectively, with different quality levels (25,50, 75, and 100).

The following figure shows a flow-chart that summarizes the steps of the first phase of the procedure.

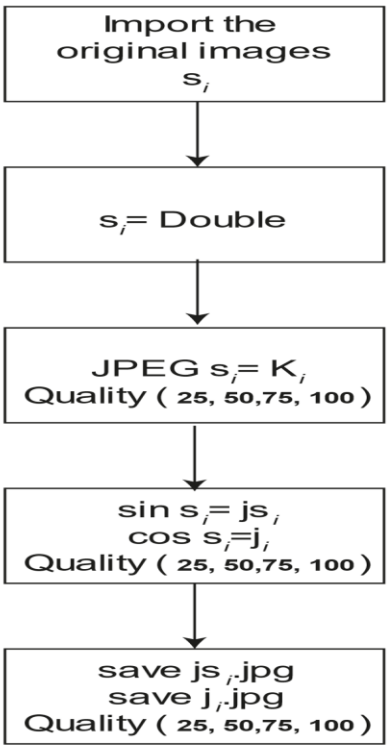


Figure 8 flow chart shows the first phase of the procedure

Second phase

Import Original images (si).

Import the JPEG compressed from the original images (ki) on different qualities (25, 50,75,100).

Import sin applied function images (jsi) saved on different qualities (25, 50,75,100).

Import cos applied function images (ji) saved on different qualities (25, 50,75,100).

Compare the sizes of the original images (si) and ki with the sizes of the sin and cos applied functions images (jsi.jpg, ji.jpg) saved on different qualities (25, 50,75,100).

Apply the error related average function psnr between original images (si) and JPEG compressed from the original images (ki).

Apply the error related average function psnr between original images (si) and sin applied function images (jsi).

Apply the error related average function psnr between original images (si) and cos applied function images (ji).

The following figure shows a flow-chart that summarizes the steps of the second phase of the procedure.

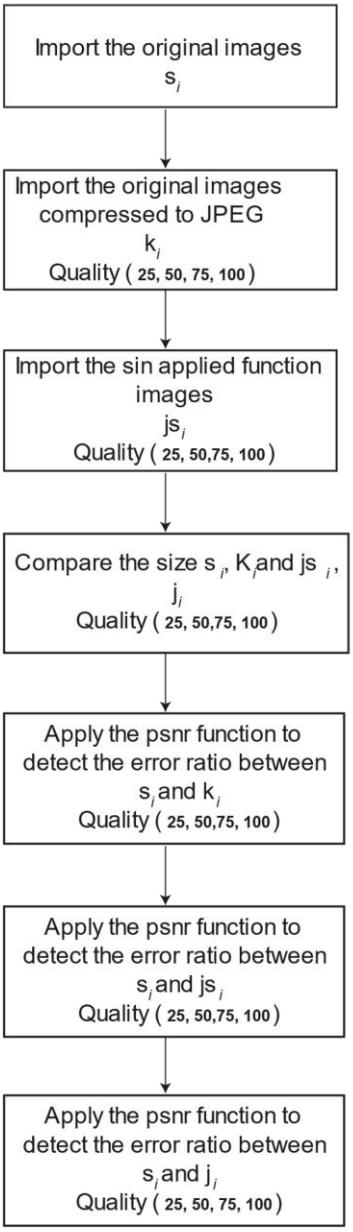


Figure 9 flow chart shows the second phase of the procedure

Findings:

Cosine function applied Images:

Cosine applied function images are found to be distorted while saving as shown in figures (10, 11,12 ,13), but these images are restored their original appearance when applying the inverse cosine function.

Figure 10 cosine function applied for images (Quality 25)

Figure 11 cosine function applied for images (Quality 50)

Figure 12 cosine function applied for images (Quality 75)

Figure 13 cosine function applied for images (Quality 100)

Sample of applying inverse cos function to the image to restore its shape as shown in figure (14)

Figure 14 inverse cosine applied to an image

Significant reduction of the stored images sizes of the cosine applied function (ji.jpg) images compared to the original sizes (si.tif) and the original transformed images to JPEG (ki.jpg) on different qualities (25, 50, 75, 100).

Tables (3, 4, 5, 6) describes the difference between image sizes of qualities (25, 50, 75, 100) respectively.

Original Image	Original Image Size	Original Compressed Image Name	Original Compressed Image Size	Applied Cos Function Name	Applied Cos Function Size
s1.tif	108493888	k_25_1.jpg'	784630	j_25_1.jpg'	623738
s2.tif	90351996	k_25_2.jpg'	708663	j_25_2.jpg'	532451
s3.tif	66396724	k_25_3.jpg'	1011106	j_25_3.jpg'	658563
s4.tif	72023342	k_25_4.jpg'	433805	j_25_4.jpg'	395186
s5.tif	59922004	k_25_5.jpg'	574195	j_25_5.jpg'	356486
s6.tif	108495924	k_25_6.jpg'	1747190	j_25_6.jpg'	983771
s7.tif	84018272	k_25_7.jpg'	819148	j_25_7.jpg'	550270
s8.tif	59913366	k_25_8.jpg'	988433	j_25_8.jpg'	587597
s9.tif	72029790	k_25_9.jpg'	868312	j_25_9.jpg'	546816
s10.tif	26488916	k_25_10.jpg'	186628	j_25_10.jpg'	162503
s11.tif	36673472	k_25_11.jpg'	664902	j_25_11.jpg'	375900
s12.tif	59919676	k_25_12.jpg'	1659747	j_25_12.jpg'	975210
s13.tif	72031614	k_25_13.jpg'	1120419	j_25_13.jpg'	688159
s14.tif	59919478	k_25_14.jpg'	1072672	j_25_14.jpg'	530731
s15.tif	59919870	k_25_15.jpg'	1010460	j_25_15.jpg'	639986
s16.tif	72026542	k_25_16.jpg'	1364778	j_25_16.jpg'	871213
s17.tif	59907810	k_25_17.jpg'	632094	j_25_17.jpg'	432110
s18.tif	59921656	k_25_18.jpg'	1157532	j_25_18.jpg'	767105
s19.tif	98252824	k_25_19.jpg'	1092888	j_25_19.jpg'	661768
s20.tif	72027640	k_25_20.jpg'	1258931	j_25_20.jpg'	610154

Table 3 shows the comparison of image sizes (quality 25)

Original Image	Original Image Size	Original Compressed Image Name	Original Compressed Image Size	percentage	Applied Cos Function Name	Applied Cos Function Size
s1.tif	108493888	k_25_1.jpg'	784630	0.72%	j_25_1.jpg'	623738
s2.tif	90351996	k_25_2.jpg'	708663	0.78%	j_25_2.jpg'	532451
s3.tif	66396724	k_25_3.jpg'	1011106	1.52%	j_25_3.jpg'	658563
s4.tif	72023342	k_25_4.jpg'	433805	0.60%	j_25_4.jpg'	395186
s5.tif	59922004	k_25_5.jpg'	574195	0.96%	j_25_5.jpg'	356486
s6.tif	108495924	k_25_6.jpg'	1747190	1.61%	j_25_6.jpg'	983771
s7.tif	84018272	k_25_7.jpg'	819148	0.97%	j_25_7.jpg'	550270
s8.tif	59913366	k_25_8.jpg'	988433	1.65%	j_25_8.jpg'	587597
s9.tif	72029790	k_25_9.jpg'	868312	1.21%	j_25_9.jpg'	546816
s10.tif	26488916	k_25_10.jpg'	186628	0.70%	j_25_10.jpg'	162503

s11.tif'	36673472	k_25_11.jpg'	664902	1.81%	j_25_11.jpg'	375900
s12.tif'	59919676	k_25_12.jpg'	1659747	2.77%	j_25_12.jpg'	975210
s13.tif'	72031614	k_25_13.jpg'	1120419	1.56%	j_25_13.jpg'	688159
s14.tif'	59919478	k_25_14.jpg'	1072672	1.79%	j_25_14.jpg'	530731
s15.tif'	59919870	k_25_15.jpg'	1010460	1.69%	j_25_15.jpg'	639986
s16.tif'	72026542	k_25_16.jpg'	1364778	1.89%	j_25_16.jpg'	871213
s17.tif'	59907810	k_25_17.jpg'	632094	1.06%	j_25_17.jpg'	432110
s18.tif'	59921656	k_25_18.jpg'	1157532	1.93%	j_25_18.jpg'	767105
s19.tif'	98252824	k_25_19.jpg'	1092888	1.11%	j_25_19.jpg'	661768
s20.tif'	72027640	k_25_20.jpg'	1258931	1.75%	j_25_20.jpg'	610154

Table 4 shows the comparison of image sizes (quality 50)

Original Image	Original Image Size	Original Compressed Image Name	Original Compressed Image Size	Applied Cos Function Name	Applied Cos Function Size
s1.tif'	108493888	k_50_1.jpg'	1010629	j_50_1.jpg'	696634
s2.tif'	90351996	k_50_2.jpg'	942165	j_50_2.jpg'	603526
s3.tif'	66396724	k_50_3.jpg'	1631897	j_50_3.jpg'	968341
s4.tif'	72023342	k_50_4.jpg'	497044	j_50_4.jpg'	414179
s5.tif'	59922004	k_50_5.jpg'	891339	j_50_5.jpg'	445460
s6.tif'	108495924	k_50_6.jpg'	2702399	j_50_6.jpg'	1471919
s7.tif'	84018272	k_50_7.jpg'	1135296	j_50_7.jpg'	678592
s8.tif'	59913366	k_50_8.jpg'	1531055	j_50_8.jpg'	866677
s9.tif'	72029790	k_50_9.jpg'	1280406	j_50_9.jpg'	720901
s10.tif'	26488916	k_50_10.jpg'	235909	j_50_10.jpg'	190080
s11.tif'	36673472	k_50_11.jpg'	1065026	j_50_11.jpg'	586122
s12.tif'	59919676	k_50_12.jpg'	2514681	j_50_12.jpg'	1511855
s13.tif'	72031614	k_50_13.jpg'	1688888	j_50_13.jpg'	977940
s14.tif'	59919478	k_50_14.jpg'	2012582	j_50_14.jpg'	815953
s15.tif'	59919870	k_50_15.jpg'	1553767	j_50_15.jpg'	944046
s16.tif'	72026542	k_50_16.jpg'	2128128	j_50_16.jpg'	1371921

s17.tif'	59907810	k_50_17.jpg'	929525	j_50_17.jpg'	571226
s18.tif'	59921656	k_50_18.jpg'	1808903	j_50_18.jpg'	1125531
s19.tif'	98252824	k_50_19.jpg'	1894049	j_50_19.jpg'	854199
s20.tif'	72027640	k_50_20.jpg'	1996566	j_50_20.jpg'	923672

Table 5 shows of the comparison of image sizes (quality 75)

Original Image	Original Image Size	Original Compressed Image Name	Original Compressed Image Size	Applied Cos Function Name	Applied Cos Function Size
s1.tif'	108493888	k_75_1.jpg'	1584424	j_75_1.jpg'	862337
s2.tif'	90351996	k_75_2.jpg'	1353210	j_75_2.jpg'	741352
s3.tif'	66396724	k_75_3.jpg'	2697824	j_75_3.jpg'	1567314
s4.tif'	72023342	k_75_4.jpg'	641092	j_75_4.jpg'	450925
s5.tif'	59922004	k_75_5.jpg'	1461085	j_75_5.jpg'	630709
s6.tif'	108495924	k_75_6.jpg'	4063826	j_75_6.jpg'	2246300
s7.tif'	84018272	k_75_7.jpg'	1690847	j_75_7.jpg'	897910
s8.tif'	59913366	k_75_8.jpg'	2360076	j_75_8.jpg'	1311799
s9.tif'	72029790	k_75_9.jpg'	2043772	j_75_9.jpg'	1020515
s10.tif'	26488916	k_75_10.jpg'	347530	j_75_10.jpg'	248412
s11.tif'	36673472	k_75_11.jpg'	1650818	j_75_11.jpg'	921412
s12.tif'	59919676	k_75_12.jpg'	3729315	j_75_12.jpg'	2293661
s13.tif'	72031614	k_75_13.jpg'	2585359	j_75_13.jpg'	1457641
s14.tif'	59919478	k_75_14.jpg'	3277226	j_75_14.jpg'	1445388
s15.tif'	59919870	k_75_15.jpg'	2368605	j_75_15.jpg'	1425515
s16.tif'	72026542	k_75_16.jpg'	3208431	j_75_16.jpg'	2120189
s17.tif'	59907810	k_75_17.jpg'	1579131	j_75_17.jpg'	865331
s18.tif'	59921656	k_75_18.jpg'	2782906	j_75_18.jpg'	1693834
s19.tif'	98252824	k_75_19.jpg'	3372345	j_75_19.jpg'	1435085
s20.tif'	72027640	k_75_20.jpg'	3037954	j_75_20.jpg'	1457219

Table 6 shows the comparison of image sizes (quality 100)

Original Image	Original ImageSize	Original Compressed Image Name	Original Compressed Image Size	Applied Cos Function Name	Applied Cos Function Size
s1.tif'	108493888	k_100_1.jpg'	17628459	j_100_1.jpg'	13130524
s2.tif'	90351996	k_100_2.jpg'	13727557	j_100_2.jpg'	6614031
s3.tif'	66396724	k_100_3.jpg'	16292760	j_100_3.jpg'	12317392
s4.tif'	72023342	k_100_4.jpg'	9340541	j_100_4.jpg'	4470669
s5.tif'	59922004	k_100_5.jpg'	11079590	j_100_5.jpg'	6721075
s6.tif'	108495924	k_100_6.jpg'	23375032	j_100_6.jpg'	16357409

s7.tif'	84018272	k_100_7.jpg'	12170064	j_100_7.jpg'	6969212
s8.tif'	59913366	k_100_8.jpg'	13124024	j_100_8.jpg'	9158425
s9.tif'	72029790	k_100_9.jpg'	14136329	j_100_9.jpg'	9090217
s10.tif'	26488916	k_100_10.jpg'	3911126	j_100_10.jpg'	3240707
s11.tif'	36673472	k_100_11.jpg'	8964666	j_100_11.jpg'	6476526
s12.tif'	59919676	k_100_12.jpg'	17396548	j_100_12.jpg'	13020527
s13.tif'	72031614	k_100_13.jpg'	15172999	j_100_13.jpg'	10723721
s14.tif'	59919478	k_100_14.jpg'	17086653	j_100_14.jpg'	11694540
s15.tif'	59919870	k_100_15.jpg'	13651563	j_100_15.jpg'	10147167
s16.tif'	72026542	k_100_16.jpg'	17484390	j_100_16.jpg'	13830740
s17.tif'	59907810	k_100_17.jpg'	11448662	j_100_17.jpg'	8858721
s18.tif'	59921656	k_100_18.jpg'	14506472	j_100_18.jpg'	10819661
s19.tif'	98252824	k_100_19.jpg'	22585316	j_100_19.jpg'	15581126
s20.tif'	72027640	k_100_20.jpg'	16772347	j_100_20.jpg'	10758631

The error relative to the average squared value (psnr) or the signal to noise ratio is also reduced significantly compared to the original compressed to JPEG images (ki) on different qualities (25, 50, 75, 100) and tables (7, 8, 9, 10) show these reductions.

Table 7 The psnr value difference with quality 25

Original Image	PSNR Original (si, ki)	PSNR Cos (si, Ji)
s1.tif	38.26829339	30.35872515
s2.tif	38.39888454	26.98675407
s3.tif	32.82862181	26.46519571
s4.tif	40.1573752	24.80886253
s5.tif	36.60696743	27.25320191
s6.tif	33.51154426	25.97426232
s7.tif	37.82796295	25.74465583
s8.tif	33.19449883	27.17898493
s9.tif	35.82509595	26.80632676

s10.tif	39.3482866	33.23814096
s11.tif	32.71365012	27.36049179
s12.tif	30.31396337	25.13246841
s13.tif	34.54902729	26.51776311
s14.tif	30.81961272	23.94484935
s15.tif	33.47821348	25.64112085
s16.tif	32.71925022	27.34389574
s17.tif	36.0499567	30.99574395
s18.tif	32.64959061	26.5442224
s19.tif	33.76004575	26.80351714
s20.tif	33.41933167	25.93452359

Table 8 The psnr value difference with quality 50

Original Image	PSNR Original (si, ki)	PSNR Cos (si, Ji)
s1.tif	41.04817096	33.98698587
s2.tif	41.59475945	32.16195937
s3.tif	34.88776803	28.97034583
s4.tif	44.02571583	28.78633373
s5.tif	39.22387351	31.38412891
s6.tif	35.98131986	29.09730293
s7.tif	40.67885293	31.12459451
s8.tif	35.39537746	29.6224647
s9.tif	38.3587788	30.190514
s10.tif	42.57353397	38.91247312
s11.tif	35.04134878	30.12632771
s12.tif	32.65138861	27.26844007
s13.tif	37.18542864	29.89373924
s14.tif	32.59716184	26.82634378
s15.tif	35.89346378	27.55576228
s16.tif	34.9842356	29.74364511
s17.tif	38.3194042	34.03251393
s18.tif	34.84314698	28.78472414
s19.tif	35.42286172	29.34828602
s20.tif	35.85281739	28.51083465

Table 9 The psnr value difference with quality 75

Original Image	PSNR Original (si, ki)	PSNR Cos (si, Ji)
s1.tif	42.76511057	35.13445312
s2.tif	43.34647019	33.63385659

s3.tif'	36.65558271	30.37176975
s4.tif'	46.21256082	30.4357349
s5.tif'	41.01266039	31.90175936
s6.tif'	38.10610988	30.14716699
s7.tif'	43.08728062	32.53270485
s8.tif'	37.32215054	31.11774121
s9.tif'	40.25113334	32.13751911
s10.tif'	44.23307194	40.73672283
s11.tif'	37.06803697	32.54782559
s12.tif'	34.75547396	29.17008896
s13.tif'	39.41915324	31.49006188
s14.tif'	34.36519156	27.99161117
s15.tif'	37.77509403	29.04143546
s16.tif'	36.81725829	31.46207769
s17.tif'	39.93250846	35.87827105
s18.tif'	36.75817814	30.30541148
s19.tif'	36.94709567	31.18969881
s20.tif'	37.93278717	30.19555711

Table 10 The psnr value difference with quality 100

Original Image	PSNR Original (si, ki)	PSNR Cos (si, Ji)
s1.tif'	50.25302947	36.72186681
s2.tif'	49.55497831	34.28543343
s3.tif'	46.58713441	33.94981012
s4.tif'	50.50985384	30.98427237
s5.tif'	50.18983018	33.21291984
s6.tif'	47.69952029	33.03194955
s7.tif'	50.23209997	34.22815693
s8.tif'	47.40103009	36.24756047
s9.tif'	49.2652394	34.6568192
s10.tif'	50.20616341	43.89406218
s11.tif'	48.68337695	39.42008509
s12.tif'	46.26875154	36.69823178
s13.tif'	49.27823313	35.34116175
s14.tif'	44.65143586	31.06289612
s15.tif'	46.26176305	32.86191206
s16.tif'	45.18859864	37.855804
s17.tif'	50.04358392	40.08890207
s18.tif'	47.31433855	34.61285396
s19.tif'	47.89596245	34.33382725

s20.tif 47.61719459 34.23749473

Sine function applied Images:

Sine applied function images are found to be not distorted while saving as shown in cosine applied function. Figures (15, 16, 17 ,18).

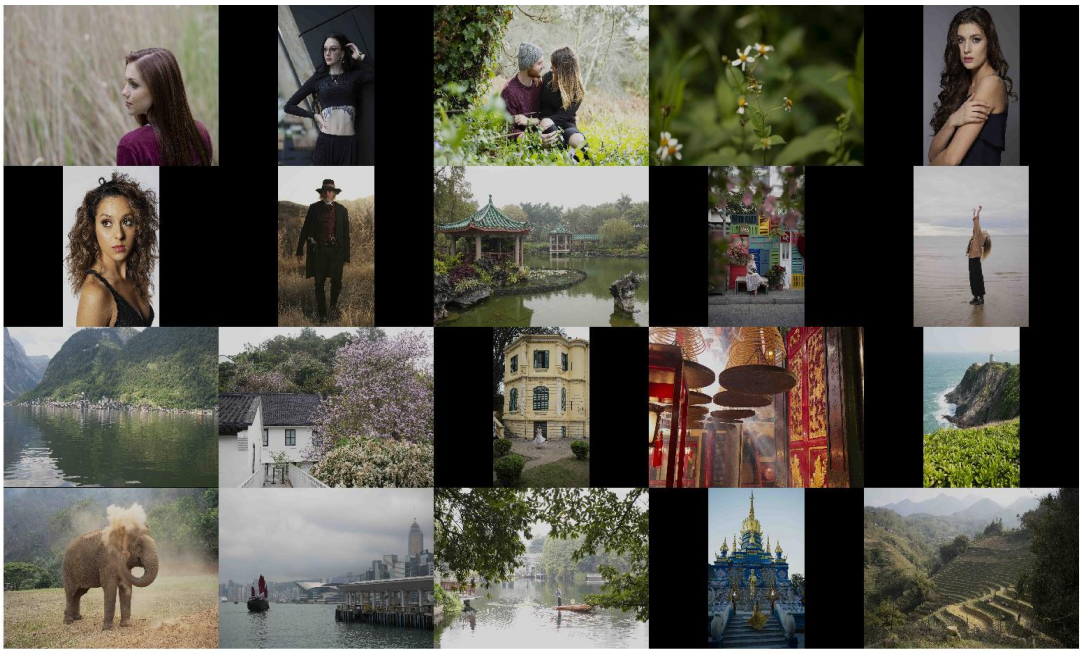


Figure 15 sine function applied for images (Quality 25)

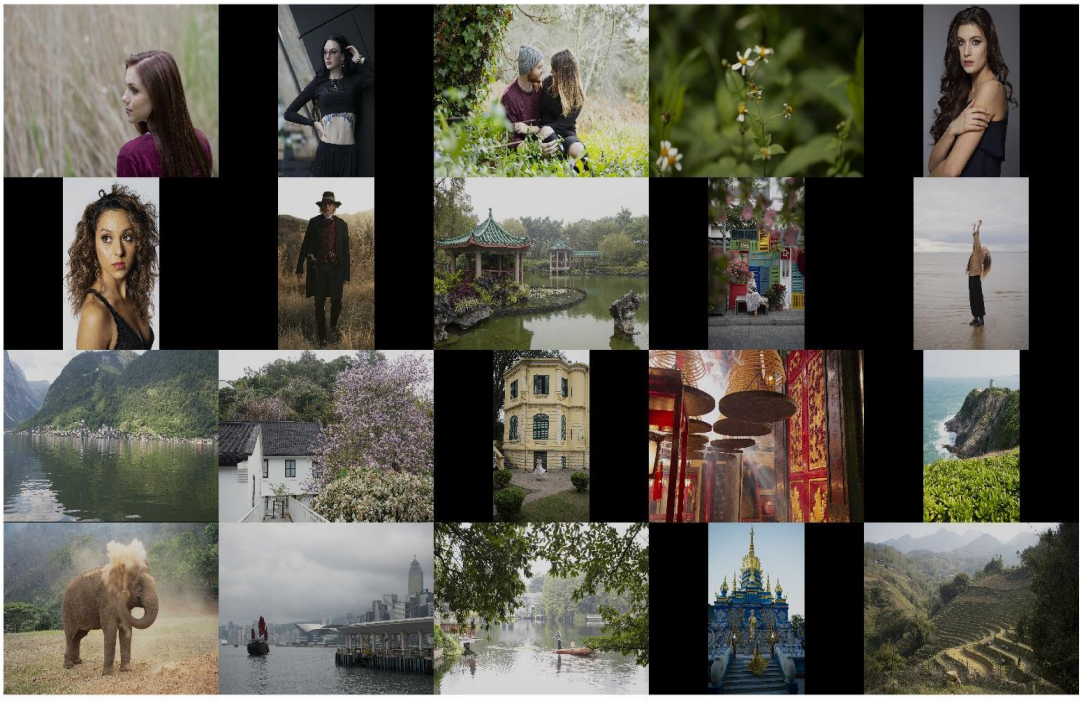


Figure 16 sine function applied for images (Quality 50)

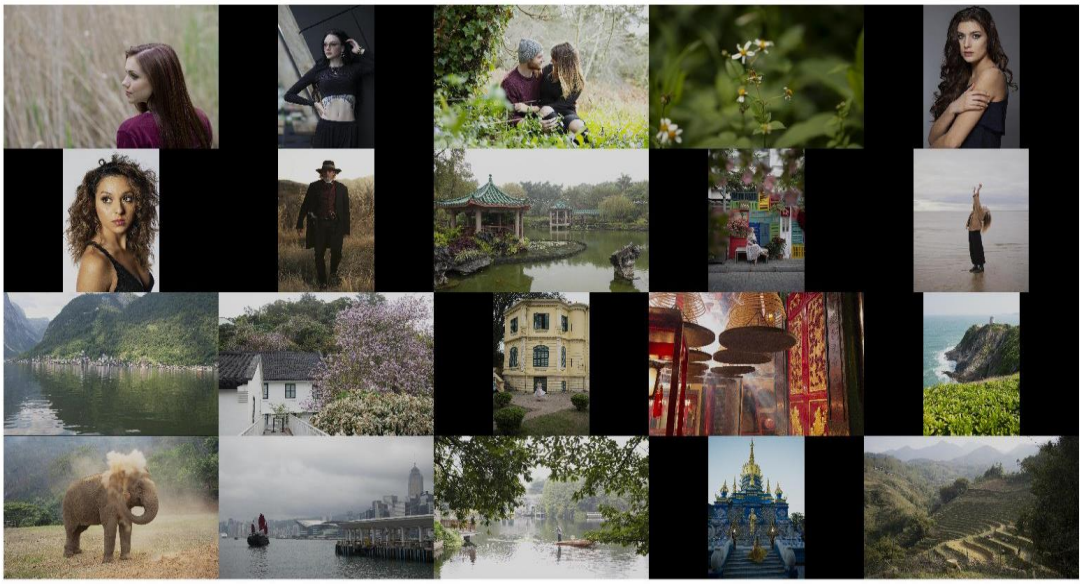


Figure 17 sine function applied for images (Quality 75)

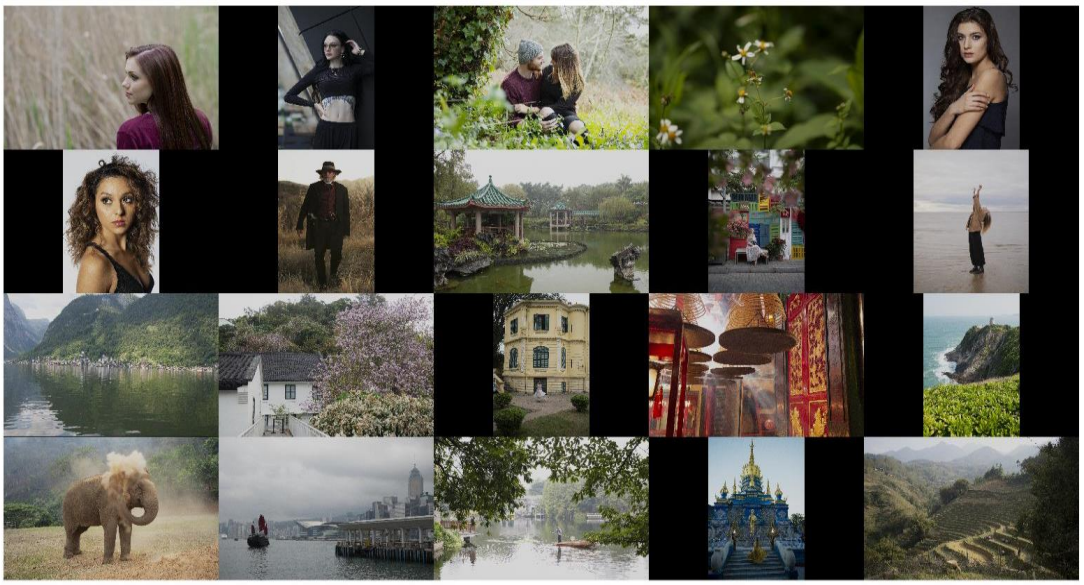


Figure 18 sine function applied for images (Quality 100)

There is a reduction of the stored images sizes of the sine applied function (jsi.jpg) images compared to the original sizes (si.tif) and the original transformed images to JPEG (ksi.jpg) on different qualities (25, 50, 75, 100).

Tables (11, 12, 13, 14) describe the difference between image sizes of qualities (25, 50, 75, 100) respectively.

Table 11 shows the comparison of image sizes (quality 25)

Original Image	Original Image Size	Original Compressed Image Name	Original Compressed Image Size	Applied Sin Function Name	Applied Sin Function Size
s1.tif'	108493888	ks_25_1.jpg'	784630	js_25_1.jpg'	767450
s2.tif'	90351996	ks_25_2.jpg'	708663	js_25_2.jpg'	692595
s3.tif'	66396724	ks_25_3.jpg'	1011106	js_25_3.jpg'	919032
s4.tif'	72023342	ks_25_4.jpg'	433805	js_25_4.jpg'	430098
s5.tif'	59922004	ks_25_5.jpg'	574195	js_25_5.jpg'	554031
s6.tif'	108495924	ks_25_6.jpg'	1747190	js_25_6.jpg'	1615891
s7.tif'	84018272	ks_25_7.jpg'	819148	js_25_7.jpg'	798435
s8.tif'	59913366	ks_25_8.jpg'	988433	js_25_8.jpg'	925129
s9.tif'	72029790	ks_25_9.jpg'	868312	js_25_9.jpg'	836137
s10.tif'	26488916	ks_25_10.jpg'	186628	js_25_10.jpg'	178504
s11.tif'	36673472	ks_25_11.jpg'	664902	js_25_11.jpg'	618335
s12.tif'	59919676	ks_25_12.jpg'	1659747	js_25_12.jpg'	1537694
s13.tif'	72031614	ks_25_13.jpg'	1120419	js_25_13.jpg'	1055092
s14.tif'	59919478	ks_25_14.jpg'	1072672	js_25_14.jpg'	986374
s15.tif'	59919870	ks_25_15.jpg'	1010460	js_25_15.jpg'	930819
s16.tif'	72026542	ks_25_16.jpg'	1364778	js_25_16.jpg'	1222861
s17.tif'	59907810	ks_25_17.jpg'	632094	js_25_17.jpg'	601662
s18.tif'	59921656	ks_25_18.jpg'	1157532	js_25_18.jpg'	1045443
s19.tif'	98252824	ks_25_19.jpg'	1092888	js_25_19.jpg'	1051583
s20.tif'	72027640	ks_25_20.jpg'	1258931	js_25_20.jpg'	1199992

Table 12 shows the comparison of image sizes (quality 50)

Original Image	Original Image Size	Original Compressed Image Name	Original Compressed Image Size	Applied Sin Function Name	Applied Sin Function Size
s1.tif'	108493888	ks_50_1.jpg'	1010629	js_50_1.jpg'	971744
s2.tif'	90351996	ks_50_2.jpg'	942165	js_50_2.jpg'	914503
s3.tif'	66396724	ks_50_3.jpg'	1631897	js_50_3.jpg'	1452848
s4.tif'	72023342	ks_50_4.jpg'	497044	js_50_4.jpg'	489791
s5.tif'	59922004	ks_50_5.jpg'	891339	js_50_5.jpg'	854347
s6.tif'	108495924	ks_50_6.jpg'	2702399	js_50_6.jpg'	2507692
s7.tif'	84018272	ks_50_7.jpg'	1135296	js_50_7.jpg'	1099982
s8.tif'	59913366	ks_50_8.jpg'	1531055	js_50_8.jpg'	1433681
s9.tif'	72029790	ks_50_9.jpg'	1280406	js_50_9.jpg'	1225612
s10.tif'	26488916	ks_50_10.jpg'	235909	js_50_10.jpg'	219389
s11.tif'	36673472	ks_50_11.jpg'	1065026	js_50_11.jpg'	996169
s12.tif'	59919676	ks_50_12.jpg'	2514681	js_50_12.jpg'	2335268
s13.tif'	72031614	ks_50_13.jpg'	1688888	js_50_13.jpg'	1581758
s14.tif'	59919478	ks_50_14.jpg'	2012582	js_50_14.jpg'	1880147

s15.tif'	59919870	ks_50_15.jpg'	1553767	js_50_15.jpg'	1428157
s16.tif'	72026542	ks_50_16.jpg'	2128128	js_50_16.jpg'	1920114
s17.tif'	59907810	ks_50_17.jpg'	929525	js_50_17.jpg'	865160
s18.tif'	59921656	ks_50_18.jpg'	1808903	js_50_18.jpg'	1635831
s19.tif'	98252824	ks_50_19.jpg'	1894049	js_50_19.jpg'	1766948
s20.tif'	72027640	ks_50_20.jpg'	1996566	js_50_20.jpg'	1905942

Table 13 shows the comparison of image sizes (quality 75)

Original Image	Original Image Size	Original Compressed Image Name	Original Compressed Image Size	Applied Sin Function Name	Applied Sin Function Size
s1.tif'	108493888	ks_75_1.jpg'	1584424	js_75_1.jpg'	1413327
s2.tif'	90351996	ks_75_2.jpg'	1353210	js_75_2.jpg'	1300630
s3.tif'	66396724	ks_75_3.jpg'	2697824	js_75_3.jpg'	2378727
s4.tif'	72023342	ks_75_4.jpg'	641092	js_75_4.jpg'	624757
s5.tif'	59922004	ks_75_5.jpg'	1461085	js_75_5.jpg'	1385026
s6.tif'	108495924	ks_75_6.jpg'	4063826	js_75_6.jpg'	3786013
s7.tif'	84018272	ks_75_7.jpg'	1690847	js_75_7.jpg'	1629894
s8.tif'	59913366	ks_75_8.jpg'	2360076	js_75_8.jpg'	2208480
s9.tif'	72029790	ks_75_9.jpg'	2043772	js_75_9.jpg'	1942105
s10.tif'	26488916	ks_75_10.jpg'	347530	js_75_10.jpg'	304396
s11.tif'	36673472	ks_75_11.jpg'	1650818	js_75_11.jpg'	1551972
s12.tif'	59919676	ks_75_12.jpg'	3729315	js_75_12.jpg'	3465361
s13.tif'	72031614	ks_75_13.jpg'	2585359	js_75_13.jpg'	2405413
s14.tif'	59919478	ks_75_14.jpg'	3277226	js_75_14.jpg'	3087175
s15.tif'	59919870	ks_75_15.jpg'	2368605	js_75_15.jpg'	2181741
s16.tif'	72026542	ks_75_16.jpg'	3208431	js_75_16.jpg'	2913390
s17.tif'	59907810	ks_75_17.jpg'	1579131	js_75_17.jpg'	1385594
s18.tif'	59921656	ks_75_18.jpg'	2782906	js_75_18.jpg'	2540368
s19.tif'	98252824	ks_75_19.jpg'	3372345	js_75_19.jpg'	3060126
s20.tif'	72027640	ks_75_20.jpg'	3037954	js_75_20.jpg'	2903351

Table 14 shows the comparison of image sizes (quality 100)

Original Image	Original Image Size	Original Compressed Image Name	Original Compressed Image Size	Applied Sin Function Name	Applied Sin Function Size
s1.tif'	108493888	ks_100_1.jpg'	17628459	js_100_1.jpg'	17027855
s2.tif'	90351996	ks_100_2.jpg'	13727557	js_100_2.jpg'	13470992
s3.tif'	66396724	ks_100_3.jpg'	16292760	js_100_3.jpg'	15276721
s4.tif'	72023342	ks_100_4.jpg'	9340541	js_100_4.jpg'	9250977
s5.tif'	59922004	ks_100_5.jpg'	11079590	js_100_5.jpg'	10871138
s6.tif'	108495924	ks_100_6.jpg'	23375032	js_100_6.jpg'	22057656

s7.tif'	84018272	ks_100_7.jpg'	12170064	js_100_7.jpg'	11927112
s8.tif'	59913366	ks_100_8.jpg'	13124024	js_100_8.jpg'	12372898
s9.tif'	72029790	ks_100_9.jpg'	14136329	js_100_9.jpg'	13855700
s10.tif'	26488916	ks_100_10.jpg'	3911126	js_100_10.jpg'	3622834
s11.tif'	36673472	ks_100_11.jpg'	8964666	js_100_11.jpg'	8661919
s12.tif'	59919676	ks_100_12.jpg'	17396548	js_100_12.jpg'	16593755
s13.tif'	72031614	ks_100_13.jpg'	15172999	js_100_13.jpg'	14593944
s14.tif'	59919478	ks_100_14.jpg'	17086653	js_100_14.jpg'	16463229
s15.tif'	59919870	ks_100_15.jpg'	13651563	js_100_15.jpg'	12894076
s16.tif'	72026542	ks_100_16.jpg'	17484390	js_100_16.jpg'	16524515
s17.tif'	59907810	ks_100_17.jpg'	11448662	js_100_17.jpg'	10770024
s18.tif'	59921656	ks_100_18.jpg'	14506472	js_100_18.jpg'	13574206
s19.tif'	98252824	ks_100_19.jpg'	22585316	js_100_19.jpg'	21518727
s20.tif'	72027640	ks_100_20.jpg'	16772347	js_100_20.jpg'	16162030

The error relative to the average squared value (psnr) or the signal to noise ratio for sine function applied for images. It is also reduced compared to the original compressed to JPEG images (ksi) on different qualities (25, 50, 75, 100) and tables (15, 16, 17, 20) show these reductions.

Table 15 The psnr value difference of applied sine function with quality 25

Original Image	PSNR Original (SI, KSI)	PSNR SIN (sI, jsI)
s1.tif	38.26829339	37.701795
s2.tif	38.39888454	37.97257488
s3.tif	32.82862181	32.12323867
s4.tif	40.1573752	39.96047191
s5.tif	36.60696743	36.27398556
s6.tif	33.51154426	32.79942439
s7.tif	37.82796295	37.53337281
s8.tif	33.19449883	32.65767519
s9.tif	35.82509595	35.45026421
s10.tif	39.3482866	37.87189749
s11.tif	32.71365012	32.27479796
s12.tif	30.31396337	29.75466511
s13.tif	34.54902729	34.00069443
s14.tif	30.81961272	30.4872087
s15.tif	33.47821348	32.76511733
s16.tif	32.71925022	32.19319416
s17.tif	36.0499567	35.23230172
s18.tif	32.64959061	31.97134141
s19.tif	33.76004575	33.22250623
s20.tif	33.41933167	33.14458747

Table 16 The psnr value difference of applied sine function with quality 50

Original Image	PSNR Original (sI, kI)	PSNR SIN (sI, jsI)
s1.tif	41.04817096	40.64688884
s2.tif	41.59475945	41.25653776
s3.tif	34.88776803	34.3041113
s4.tif	44.02571583	43.8503024
s5.tif	39.22387351	38.97014476
s6.tif	35.98131986	35.25200234
s7.tif	40.67885293	40.39633055
s8.tif	35.39537746	35.03710744
s9.tif	38.3587788	38.06152226
s10.tif	42.57353397	41.27150858
s11.tif	35.04134878	34.64196963
s12.tif	32.65138861	32.11594281
s13.tif	37.18542864	36.69750649
s14.tif	32.59716184	32.2825692
s15.tif	35.89346378	35.40053833
s16.tif	34.9842356	34.59760627
s17.tif	38.3194042	37.74426384
s18.tif	34.84314698	34.21175087
s19.tif	35.42286172	35.08109495
s20.tif	35.85281739	35.65024612

Table 17 The psnr value difference of applied sine function with quality 75

Original Image	PSNR Original (si, ki)	PSNR SIN (si, jsi)
s1.tif	42.76511057	42.17827668
s2.tif	43.34647019	43.02981806
s3.tif	36.65558271	36.09254772
s4.tif	46.21256082	45.99749167
s5.tif	41.01266039	40.70679497
s6.tif	38.10610988	37.47078234
s7.tif	43.08728062	42.77061933
s8.tif	37.32215054	36.97073523
s9.tif	40.25113334	39.98897359
s10.tif	44.23307194	43.21098649
s11.tif	37.06803697	36.68535776
s12.tif	34.75547396	34.2217884
s13.tif	39.41915324	38.94175222

s14.tif'	34.36519156	34.03931224
s15.tif'	37.77509403	37.34525019
s16.tif'	36.81725829	36.55323533
s17.tif'	39.93250846	39.52036417
s18.tif'	36.75817814	36.15388945
s19.tif'	36.94709567	36.58179057
s20.tif'	37.93278717	37.7334229

Table 18 The psnr value difference of applied sine function with quality 100

Original Image	PSNR Original (si, ki)	PSNR SIN (si, jsi)
s1.tif'	50.25302947	48.31218884
s2.tif'	49.55497831	48.7709044
s3.tif'	46.58713441	45.36350357
s4.tif'	50.50985384	49.99578943
s5.tif'	50.18983018	49.203174
s6.tif'	47.69952029	46.06320396
s7.tif'	50.23209997	49.21457808
s8.tif'	47.40103009	46.63706163
s9.tif'	49.2652394	48.53367134
s10.tif'	50.20616341	46.90878967
s11.tif'	48.68337695	47.61403014
s12.tif'	46.26875154	45.38926002
s13.tif'	49.27823313	48.15325285
s14.tif'	44.65143586	44.49738528
s15.tif'	46.26176305	45.2326604
s16.tif'	45.18859864	45.00451437
s17.tif'	50.04358392	47.79650458
s18.tif'	47.31433855	46.12776158
s19.tif'	47.89596245	46.28986278
s20.tif'	47.61719459	47.06684353

Results

Cosine Applied function:

The percentage of storage sizes of the original images to both the original image compression after applying the cosine function are reduced to the values as shown in the following table:

Table 19 shows the percentage of storge size reduction on different quality values

Before cos function	After cos function	Quality value
0.60%-2.77%	0.55%-1.63%	25
0.69%-4.20%	0.58%-2.52%	50
0.89%-6.22%	0.63%-3.83%	75
12.97%-29.03%	6.21%-21.73%	100

On the other hand, the error relative to the average squared value of the signal or the psnr showing the minimum and the maximum difference between the value before and after the cos function was applied in (db) as in the following table:

Table 20 Shows the minimum and maximum difference of psnr in db on different quality values

ki-ji Minimum psnr (db)	ki-ji Maximum psnr(db)	Quality Value
5.054212748	15.34851267	25
3.661060846	15.2393821	50
3.496349113	15.77682592	75
6.312101239	19.52558147	100

From table 19 and 20 it is shown that the average reduction of psnr is high about 16.47 db due to the applying of the cos Function to gain a storage size reduction of average 4.35% on different qualities.

Sine Applied function:

The percentage of storage sizes of the original images to both the original image compression after applying the sine function are reduced to the values as shown in the following table 21:

Table 21 shows the percentage of storge size reduction after applying the sin function on different quality values

Before sin function	After sin function	Quality value
0.60%-2.77%	0.60%-2.57%	25
0.69%-4.20%	0.68% to 3.90%	50
0.89%-6.22%	0.87%-5.78%	75
12.97%-29.03%	12.84%-27.69%	100

While the psnr of minimum and the maximum difference between the value before and after the sin function was applied in (db) as shown in the following table

Table 22 Shows the minimum and maximum difference of psnr after applying the sin function in db on different quality values

ksi-jsi Minimum psnr (db)	ksi-jsi Maximum psnr(db)	Quality Value
0.196903284	1.476389108	25
0.175413433	1.302025389	50
0.199364273	1.022085452	75
0.154050583	3.297373744	100

From tables 21 and 22 it is shown that the average reduction of psnr is low about 1.77 db due to the applying of the sin function to gain a storage size reduction of average 3.75% on different qualities.

Conclusion:

- Using the trigonometric functions (sin and cos) will effectively reduce the image storage sizes more than without using these functions.
- The use of sin function is more effective than using the cos function when converting to JPEG compression because when the cos function is used it is possible to achieve a 4.35% average reduction in storage size with the cost of average of 16.47 db difference between the original compression and the use of cos function before converting to JPEG. While using the sin function can achieve a 3.75% with a cost of 1.77 db difference between the original compression and the use of sin function before converting to JPEG.
- Using the cos function needs to be inverse transformed to the inverse cos to restore its original appearance which means one step more in the processing load over the computer.

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