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A Proposed Modification of Baseline JPEG Standard Image Compression Technique

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Abstract— Image compression is the transformation of image data in an arrangement to a more compressed form. The objective of image compression is to reduce redundancy of the image data in order to be able to store or transmit data in an efficient form. It is used in many applications like broadcast television; remote sensing via satellite, aircraft, radar or sonar; teleconferencing; computer communications; and facsimile transmission and medical images storage for patient monitoring systems. JPEG is one of the most popular compression techniques in the field of image compression. It has both lossy and lossless image compression part. The baseline mode of JPEG standard is a lossy compression technique which is the most popular among baseline, progressive and hierarchical modes of lossy part. Though the compression performance in baseline JPEG standard is good but still it needs to be improved. In this paper, the baseline JPEG compression standard has been modified to increase the performance. The proposed modification is done in entropy coding where a well known encoding technique; the arithmetic coding technique has been used. The typical baseline JPEG standard and proposed baseline JPEG standard modification has been implemented and performance has been measured. The experimental data states that the performance of the proposed baseline JPEG standard modification better than the typical lossy baseline JPEG standard in terms of space savings though the compression and decompression time is higher.

Index Terms— Coding redundancy, Interpixel redundancy, Sycho visual redundancy, DCT, Arithmetic coding, Huffman coding, Zig-zag scanning, Quantization matrix.

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1 Introduction

Enormous storage capacity would require storing data that are associated with visual information because they contain so much information. A 24 bit color image with 512x512 pixels will occupy 768 KB storage on a disk. To transmit such an image over a 28.8 Kbps modem would take almost 4 minutes [1]. That's why image compression techniques are required to reduce the number of bits for storing or transmitting images. Image compression deals with sinking the amount of data required to represent a digital image by removing of redundant data. A common characteristic of most images is that the neighboring pixels are correlated and therefore contain redundant information [2]. In an image, which consists of a sequence of pixels, there are three types of redundancies [3], [4] in order to compress file size. They are coding redundancy, interpixel redundancy and sycho visual redundancy. The foremost task then is to find less correlated representation of the image [5] and to reduce the redundancy of the image and to store or transmit data in an efficient form. The underlying basis of the reduction process is the removal of redundant data [6].

The two types of image compression techniques are lossless and lossy technique. Lossless image compression algorithms allow the original data to be perfectly reconstructed from the compressed data. On the other hand, lossy compression algorithms retrieved data may be different from the original, but is "close enough" to be useful in some way. Compression ratio is higher than that of lossless compression. Lossy technique causes image quality degradation in each compression or decompression step [7]. Lossy compression is generally used in multimedia data processing or transfer, where a certain amount of data loss will not be detected by most users. In the field of image compression, JPEG (Joint Photographic Experts Group) standard is an international compression standard for continuous-tone still image, both grayscale and color. JPEG is one of the most successful still image compression standards. The JPEG standard is teamwork along with the International Telecommunication Union (ITU), International Organization for Standardization (ISO), and International Electrotechnical Commission (IEC). JPEG was formally accepted as an international standard in 1992 [8, 9]. The JPEG standard has two basic compression methods. The DCT-based method is specified for lossy compression, and the predictive method is specified for lossless compression. A simple lossy technique called baseline, which is a DCT-based methods, has been widely used today and is sufficient for a large number of applications. DCT based baseline JPEG still provides a good solution in the field here lossy compression is desirable and low complexity is of higher priority. Another successful image compression technique, JPEG2000 [10] reaches much better results than traditional DCT based baseline JPEG standard. It offers very high compression ratios over the current JPEG format. But practically JPEG2000 is a resource hog that means compressing data requires lots of CPU usage and more demanding in memory. That's why, in this paper a modification in the typical baseline JPEG standard has been proposed to enrich the compression ratio or space savings of baseline JPEG standard without affecting the image quality.

2 Description of Existing Baseline JPEG Image Compression Technique

JPEG is the first ISO/ITU-T standard for continuous tone still images. It allows both lossy and lossless coding of still images compression. JPEG gives good compression results for lossy compression with the smallest amount complexity [8].

There are several modes defined for JPEG [11, 8], including baseline, lossless, progressive and hierarchical. The baseline mode is the most popular one and supports lossy coding only.

This baseline uses an encoding scheme based on the Discrete Cosine Transform (DCT) to achieve compression. In the baseline mode, the baseline JPEG standard has the following steps.

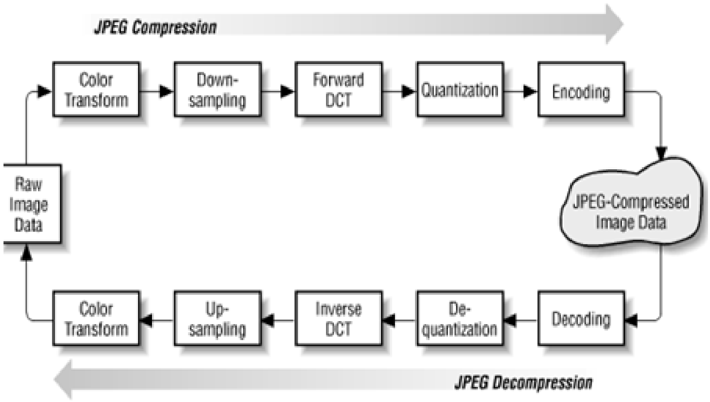

Fig 1. Baseline JPEG Compressor and Decompressor

2.1 Color Space Conversion

The conversion from RGB to YC_bC_r color space is usually the first step toward compressing an image that separates the luminance component, from chrominance component. YC_bC_r (256 levels) can be computed directly from 8-bit RGB as follows [12, 9].

$$\begin{aligned} Y &= 0.299R+0.587G+0.114B \\ C_b &= -0.1687R-0.3313G+0.5B+128 \\ C_r &= 0.5\,R-0.4187\,G-0.0813\,B+128 \end{aligned} \quad \ldots\ldots\ldots\ldots(1)$$

2.2 Transform Coding

DCT based baseline JPEG use DCT as transform coding. To apply DCT, first image is divided into 8x8 blocks of pixels and processed from left to right, top to bottom. To run through the DCT perform a level shift of 128, thus changing the range from (0,255) to (-128,127) [8]. The mathematical functions of 2D DCT used for JPEG are as follows.

i) Discrete Cosine Transform (DCT)

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

$$\text{for } u=0,\ldots,7 \text{ and } v=0,\ldots,7 \quad \ldots(2)$$

$$\text{where } C(k)=\begin{cases}1/\sqrt{2} & \text{for } k=0\\ 1 & \text{otherwise}\end{cases}$$

ii) ***Inverse Discrete Cosine Transform (IDCT)***

$$f(x,y)=\frac{1}{4}\sum_{u=0}^{7}\sum_{v=0}^{7}C(u)C(v)F(u,v)\cos\left[\frac{\pi(2x+1)u}{16}\right]\cos\left[\frac{\pi(2y+1)v}{16}\right] \quad \ldots(3)$$

$$\text{for } x=0,\ldots,7 \text{ and } y=0,\ldots,7$$

For a typical 8x8 sample block from a typical source image, most of the spatial frequencies have zero or near-zero amplitude and need not be encoded. At the decoder the IDCT reverses this processing step. Mathematically, the DCT is one-to-one mapping for 64-point vectors between the image and the frequency domains. In principle, the DCT introduces no loss to the source image samples [9].

2.3 Quantization

Quantization is the step where data is thrown away, to achieve further compression [8]. During quantization, every element in the 8x8 FDCT matrix is divided by a corresponding step size in a quantization matrix Q to yield a matrix QFDCT followed by rounding to the nearest integer [8].

$$Q_{FDCT}(u,v)=round\left(\frac{FDCT(u,v)}{Q(u,v)}\right) \quad \ldots\ldots\ldots(4)$$

This output value is normalized by the quantizer step size. De-quantization is the inverse function, which in this case means simply that the normalization is removed by multiplying by the step size, which returns the result to a representation appropriate for input to the IDCT [8].

$$FDCT^{Q'}(u,v)=Q_{FDCT}(u,v)*Q(u,v) \quad \ldots\ldots\ldots(5)$$

The goal of quantization is to reduce most of the less important high frequency coefficients to zero, the more zeros we can generate the better the image will compress.

2.3 Entropy Coding

Entropy coding is a special form of lossless data compression. It involves arranging the image components in a zig-zag order, employing run-length encoding (RLE) algorithm that groups similar frequencies together, inserting length coding zeros, and then using Huffman coding.

After doing the DCT transform and quantization over a block of 8x8 values, traversing in zig-zag the 8×8 matrix a vector with 64 coefficients (0, 1,...,63) is produced. The reason for this zig-zag traversing is that, the 8×8 DCT coefficients arrange in the order of increasing the spatial frequencies. So, the vector of 64 elements is sorted by the criteria of the spatial frequency and a lot of consecutive zero can get.

The first element is called DC coefficient and other 63 element is called AC coefficients [8, 13]. Now run length encoding (RLE) is applied to 63 AC coefficients. The DC coefficient contains a lot of energy, it usually has much larger value than AC coefficients, and we can notice that there is a very close connection between the DC coefficients of adjacent blocks. So, the DCT based baseline JPEG standard encode the difference between the DC coefficients of consecutive 8×8 blocks rather than its true value. The mathematical represent of the difference is Diffi = DCi – DCi-1 and we set DC0 = 0. DC of the current block DCi will be equal to DCi-1 + Diffi . So, in the JPEG file, the first coefficient is actually the difference of DCs. Then the difference is Huffman encoded together with the encoding of AC coefficients.

Instead of storing the actual value, the JPEG standard speci-

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fies that we store the minimum size in bits in which we can keep that value (it's called the category of that value) and then a bit-coded representation of that value.

3 Proposed Modification in Baseline JPEG Image Compression

Basically the proposed method is the modification of existing DCT based baseline JPEG compression technique. The modification is proposed in entropy coding step. In the proposed baseline JPEG standard modification the color conversion, DCT, quantization and zig-zag scanning steps are same as the typical baseline JPEG technique. Modification is done after zig-zag sequencing where the following steps are followed. In the proposed DCT based baseline JPEG standard modification, Run Length Encoding (RLE) has been thrown away and Arithmetic Coding has been introduced. Arithmetic Coding is the most powerful technique for statistical lossless encoding that has attracted much attention in the recent years [14]. The basic concept of arithmetic coding can be traced back to Elias in the early 1960s [15]. Arithmetic coding is accommodates adaptive models easily and is computationally efficient [16].

3.1 DC Differential coding

To reduce the correlation differential pulse code modulation (DPCM) or DC differential coding is used. In this process the first DC value of first block to pass through to the entropy coding module. Afterword the difference between the current block DC value and the previous block DC value is passed. This process is done raster order throughout all blocks of the image [17].

3.2 Apply Huffman Encoding

After applying DPCM on DC coefficients and zig-zag scanning Huffman entropy coding is applied to all AC and DC values of whole image and get separate bit of streams for AC and DC value. The basic idea in Huffman coding is to assign short code words to input blocks with high probabilities and long code words to the input which has low probabilities [18]. To apply Huffman encoding negative values are converted to positive by adding 128 to each coefficient.

3.3 Block Creation

This step deals with the bit stream that is produced after Huffman encoding. Blocks are created with the whole bit stream and the length of the block is 8 that means a block is created with 8 successive bits. Some extra bits may be used for padding the last block which is discarded in decoding. Now each block is treated as symbols and can get a number of symbols for the whole bit stream which are considered for further calculation.

3.4 Apply Arithmetic encoding

Arithmetic encoding is applied to the symbols, Symbols are arranged according to their probability and bits are assigned to each symbol. In the proposed method Huffman and Arithmetic encoding is used, so the Huffman code table and Arithmetic code table are included in the compressed file as side information.

The overall proposed baseline JPEG standard encoder can be as the following Fig 2.

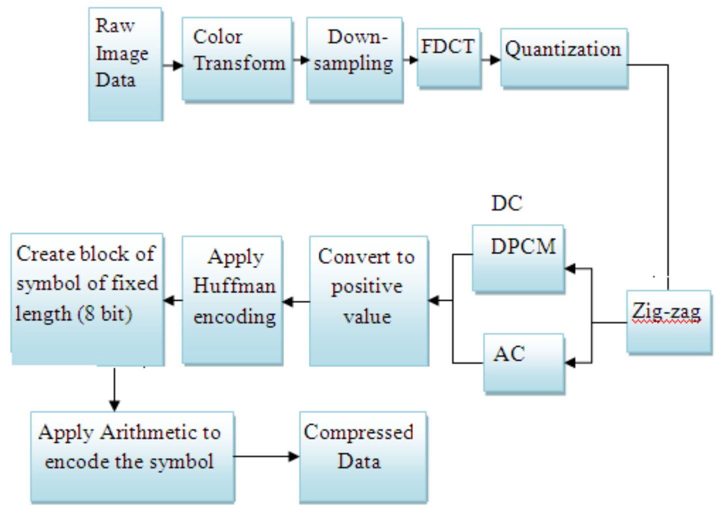

Fig 2. Block diagram of proposed baseline JPEG encoder

And the algorithm may be written as follows

Proposed Algorithm

Step 1: Transform the image from RGB to YCbCr color model.

Step 2: Divide the image into non-overlapping 8×8 sub images blocks.

Step 3: Shift the gray-levels in the range between [-128, +127].

Step 4: Apply DCT on each sub-image.

Step 5: Quantize the coefficient and the less significant coefficients are set to zero.

Step 6: Reorder the coefficients according zig-zag scanning and apply DPCM on DC coefficients.

Step 7: Add 128 to AC and DC Coefficient to make it positive.

Step 8: Apply Huffman encoding to all image value.

Step 9: Create blocks of 8 bit (successive) length with whole bit stream and treat as symbols.

Step 10: Apply Arithmetic encoding to each of the symbols.

Step 11: Get Encoded binary image data.

To reconstruct the image, reverse process of the proposed algorithm are carried out.

4 Illustration of the Proposed System

The image is first subdivided into blocks. This section verifies the system by a single 8x8 block. Generally a block of pixels of size is processed left to right and top to bottom. Consider the following pixel matrix in Fig 3.

143	173	200	211	220	224	227	229

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132	151	175	191	207	217	223	227
207	209	212	211	208	206	209	123
231	232	230	228	226	222	217	211
231	231	232	232	231	231	230	228
231	231	232	232	232	232	232	232
231	231	231	232	232	232	232	232
231	231	231	231	231	231	232	232

Fig 3. Input pixel matrix

The encoding process begins by level shifting the pixels of the original sub images by -27 or -128 gray levels. The reason for level shifting is to convert 8-bit image from range 0 to 256 to the range -128 to +127 to apply DCT. The resulting shifted array is given in following Fig 4.

15	45	72	83	92	96	99	101
4	23	47	63	79	89	95	99
79	81	84	83	80	78	81	85
103	103	102	100	98	94	89	83
103	103	104	104	103	103	102	100
103	103	104	104	104	104	104	104
103	103	103	104	104	104	104	104
103	103	103	103	103	103	104	104

Fig 4. Level shifted matrix

After applying the forward 2D DCT, the transformed matrix becomes a DCT matrix and is shown in following Fig 5.

729	-51	-22	-10	-4	-1	0	1
-106	-70	-25	-12	-5	-3	0	1
-37	-60	-15	-9	-3	-2	0	0
15	-25	-11	-4	-3	-1	0	0
27	14	-6	0	-3	0	-1	0
22	30	0	0	-1	0	-1	0
14	23	6	-3	1	0	0	0
7	10	5	-3	1	0	0	0

Fig 5. Output DCT matrix

Luminance quantization matrix is used for brightness component and chrominance quantization matrix is used for color component of an image. If in quantization stage luminance quantization matrix is used to quantize the DCT transformed array then the transformed truncated coefficients will be as the following Fig 6.

46	-5	-2	-1	0	0	0	0
-9	-6	-2	-1	0	0	0	0
-3	-5	-1	0	0	0	0	0
1	-1	-1	0	0	0	0	0
2	1	0	0	0	0	0	0
1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Fig 6. Quantized matrix

This transformed and normalized form has a large number of zero-valued co-efficient. When the coefficients are reordered according the Zig-zag order can get the following 1-D coefficient sequence.

[46 -5 -9 -3 -6 -2 -1 -2 -5 1 2 -1 -1 -1 0 0 0 0 -1 1 1 0 1 EOB]

Then after DPCM on DC components and make the coefficients positive by adding 128 to each value the 1-D coefficients will be.

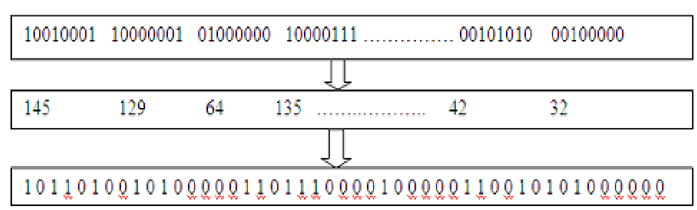
[132 123 119 125 122 126 127 126 123 129 130 127 127 127 128 128 128 128 127 129 129 128 129 EOB]

After applying Huffman encoding the following bit stream can get.

10010 0011000 000101000 000100 0011101 00011 011 00011 0011000 010 00001 011 011 011 1 1 1 1 011 010 010 1 010 0010

Thus the number of bits required to represent the entire 8×8 sub image is 92. Here 0010 indicate end-of-block. This observation is done only on a 8×8 sub image of the picture and this process is applied on whole image.

This stream of bit is grouped into a block of 8 bits. As the last block contain 0010 four 0 will be added to the last four bit positions to complete the last block. Then all the blocks are treated as symbols. The symbols are encoded using Arithmetic encoding process and a dictionary is created according to the probability of occurrence of the symbol and the following bit streams are found.



After applying Arithmetic encoding 93 bits are reduced to 49 bits. So it can be seen that more compression is found here.

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5 Performance Analysis

There are three performance evaluation criteria have been used in this experiment. They are described as following.

a. Space Savings: The first and most important criterion is space savings. Space savings of compression technique defines the reduction of data. The space savings is calculated using the compressed image file size and original image file size as the following equation.

$$\text{Space savings} = \frac{\text{uncompressed file size} - \text{compressed file size}}{\text{uncompressed file size}} \times 100\% \quad \ldots (6)$$

b. Compression and Decompression Time: Compression time is defined by the total required time to compress the image file and decompression time is the required time to decompress the compressed image file. The compression and decompression time is taken from the CPU time to compress the image and decompress the compressed image.

c. Peak Signal to Noise Ratio (PSNR): PSNR is used for the measurement of quality of an image. In general, reconstructed images with PSNR values greater than 30 dB are considered to be in good quality and acceptable to most image applications [19]. PSNR is calculated using the following equations [12].

$$MSE = \sqrt{\frac{\sum_{x=0}^{W-1}\sum_{y=0}^{H-1}\left[f(x,y) - f'(x,y)\right]^2}{WH}} \quad \ldots\ldots (7)$$

$$PSNR = 20\log_{10}\frac{255}{MSE}$$

MSE is called squared error loss. MSE measures the average of the square of the "error".

To evaluate the performance of the proposed DCT based baseline JPEG standard and the typical DCT based baseline JPEG standard image compression models, 10 bitmap (BMP) colored image samples has been taken in this experiment. The samples are compressed and decompressed using the both models. In both models the image PSNR value is kept same. Following table shows the experimental result. It shows the original image size, compressed image size using typical lossy baseline JPEG standard and the proposed baseline JPEG modification.

TABLE 1. Compressed image size using typical baseline JPEG and the proposed baseline JPEG modification

Image Samples	Original File Size (kb)	Compressed File Size (kb)		PSNR
	BMP	Lossy JPEG	Proposed Lossy JPEG	
sample 1	768	34.92	31.53	36.42
sample 2	497	18.70	15.68	36.70
sample 3	768	21.80	16.69	41.12
sample 4	721	37.75	34.14	34.82
sample 5	618	30.36	27.32	34.09
sample 6	900	40.40	36.79	34.36
sample 7	918	36.72	30.95	35.97
sample 8	603	36.57	32.98	33.28
sample 9	703	35.19	32.62	38.50
sample 10	843	27.80	23.15	37.12

From above table one can observe that for all samples the proposed JPEG standard reduce the compressed file size more than typical JPEG standard without affecting the PSNR value of the image. Using the above Table 1, the space savings of both image compression techniques is calculated by following equation 6 and can be represented by the following fig 7.

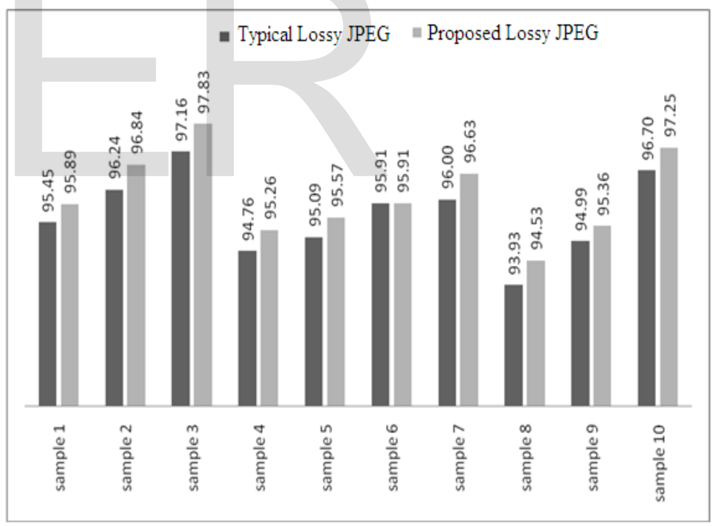

Fig7. Space savings of typical baseline JPEG and the proposed baseline JPEG modification

The above fig 7 states that for all samples the space savings in the proposed baseline JPEG modification is more than typical baseline JPEG model.

The following Table 2 shows the encoding and decoding time required for above sample images for typical baseline JPEG standard and proposed baseline JPEG modification model.

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TABLE 2. Compression and decompression time of typical baseline JPEG and the proposed baseline JPEG modification

Image Samples	Typical baseline JPEG		Proposed baseline JPEG Modification	
	Compress Time(sec)	Decompress Time(sec)	Compress Time(sec)	Decompress Time(sec)
sample 1	21.803	25.169	27.425	258.595
sample 2	8.248	13.128	16.957	79.342
sample 3	10.757	15.476	14.696	76.996
sample 4	17.341	25.813	24.759	334.765
sample 5	17.454	22.001	21.199	264.176
sample 6	27.389	30.481	25.874	281.394
sample 7	23.341	27.760	28.790	319.311
sample 8	10.394	14.781	27.104	432.322
sample 9	19.329	24.963	27.837	234.126
sample 10	16.027	17.983	18.616	123.921

The compression time and decompression time in the above table depends on the machine environment. It varies from machine to machine. The data in the TABLE 2 shows that compression and decompression time is more in proposed baseline JPEG modification than in the typical baseline JPEG standard though the space savings is more in proposed baseline JPEG modification than in the typical baseline JPEG standard.

6 Conclusion

Lossy image compression is a class of image compression algorithms that allows the exact original data to be reconstructed from the compressed data. Baseline JPEG standard image compression is one of the most popular and efficient technique for lossy image compression. Though the technique has good compression ratio or space savings but still the savings should be improved. In this paper, a modified baseline JPEG standard has been proposed which improves the performance. To measure the performance of proposed baseline JPEG standard technique three criteria space savings, compression and decompression time, PSNR has been defined in section IV. Ten (10) image samples have been taken for the experiment. For these samples, the performance of typical baseline JPEG and proposed baseline JPEG have been measured where PSNR has been kept same for both techniques. The measured value of space savings figured as Fig 7 and compression and decompression time has been recorded in TABLE 2. From Fig 7, it is seen that the space savings of the proposed baseline JPEG is greater than typical baseline JPEG though the compression and decompression time is greater in proposed baseline JPEG standard. So it can be concluded here, the proposed baseline JPEG standard works better in terms of space savings than typical baseline JPEG standard.

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