International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Compression of Visual Images based on Histograms using Quadtree Algorithms

Nawaf A. Alqwaifly*[1]

Submitted: 17/01/2025 **Revised:** 27/02/2025 **Accepted:** 10/03/2025

Abstract: Over the last few years, there has been an exponential growth in the demand for images and video sequences via wireless networks. The result has been that image and video compression has become an increasingly crucial issue in decreasing the cost of storing and transmitting data. The goal of visual image compression is to reduce the amount of information required to represent an image. To compress an image efficiently, a technique is used to reduce the space required and to increase the efficiency of transferring the image over the network in order to improve access to the images. In this paper, we present a histogram-based visual image compression technique based on Quadtrees. Using this technique, the image is divided into blocks in order to reduce the space necessary for the whole image. This ensures the efficient transmission of each block. A histogram of the image block is used to analyse the compression of an image. The results of the experiments indicate that the algorithms provide a compression ratio that varies between 0.13 and 0.61. Moreover, the results prove that the method is able to improve the compression performance and can achieve a similarity between the compression ratio and image quality.

Keywords: *Image Histogram; Quadtree; Image Compression; Block Groups; Peak to peak Signal to Noise Ratio (PSNR).*

1. Introduction

A visual image is compressed in order to reduce the amount of redundant information in the visual image. This is done for the purpose of reducing the storage requirements and communication costs of the image. Increasing the communication bandwidth and the storage capacity of the medium is equivalent to reducing the storage requirements. For the future design of advanced communication systems and advanced multimedia applications, effective compression techniques are still a challenge. There is a way to represent an image as a combination of pixel intensity and redundancy. An image's pixel intensity must be permanently held in its original form in order to permit the correct construal of the shape of the image. An image that is redundant can be deleted when it is no longer required or may have to be re-inserted when it is no longer needed. As a general matter, it is common for redundant information to be reinserted to generate the original image as it appears in its visual form [1].
Several techniques have been developed for image compression that can be used to extract appropriate and effective features from images. Some of the most commonly used visual features have been divided into different groups [2]. However, some features are actually members of two or more groups. It should be noted that these features are independent of a particular domain and can be applied to all types of image compression systems [3]. A Quadtree approach is a simple technique for displaying different levels of resolution within an image, by partitioning the image into blocks based on the area occupied by Quadtree structures. According to research studies, Quadtree based image segmentation can be a very effective and efficient mechanism for isolating the unique emotional significance blocks which are best suited for the individual segment categories allowing different coding strategies to be used [4-6].
The Quadtree decomposition is a technique for representing images of varying levels of resolution [7]. There are three different representations of this representation; a binary image in [8]; a grayscale image in [9]; and a color image in [10]. In general, Quadtree decomposition is used to reduce the size of images [11], to enhance the complexity of images [12] and in some cases to extract features calculations [13,14]. A second method is to divide the image into different areas and then calculate the color characteristics of each area [15-17]. It is a method of improving and making similar blocks appear to be effective histograms by dividing an image into sub-blocks and capturing useful information from each block.
In this paper, a histogram based image compression algorithm called Quadtree visualization is presented. The image is divided into blocks, and the blocks are saved in a block that can be easily restored when necessary. The distortion of the image is measured by the PSNR (Peak to Peak Signal to Noise Ratio) and compression ratio (CR). Typically, these ratios are used as a measure of the quality of the original and compressed images to determine whether they are of equal quality.

2. Compression of Visual Images

There is a method of compressing images, where an input image I is used to create a group of blocks which represent an image "Ug" with a smaller number of pixel values than the original image. Compressed data is stored in a storage block or transmitted to the receiver block (reception). The

[1] *Department of Electrical Engineering, College of Engineering, Qassim University, Buraydah, 52571, Saudi Arabia*

* *Corresponding Author Email: nkoiefly@qu.edu.sa*

data is encoded according to a quad-tree root encoding based on the threshold value of the image. During the decompression process, the compression process which was applied in the encoder is reversed. Figure 1 shows a reconstructed image produced in Figure 1 from the root blocks which needs to be compressed.

Figure 1. A block diagram illustrating the visual image compression process

2.1. Quadtree Approach

A Quadtree is a type of tree data structure in which each internal node has a set of four blocks. Node in the tree either has exactly four blocks (tree node) or doesn't have any blocks (leaf node). A Quadtree is most commonly used as a method of segmenting a two-dimensional space into four blocks [18]. A Quadtree can be constructed by dividing each block into four equal squares or rectangles. The Quadtree algorithm is involved in an image segmentation block which is more like the image itself, than the image itself. In a traditional Quadtree grid, a level is divided into four equal sub-square blocks. These blocks are tested to determine if they fulfill the threshold condition. In the event that a block meets the threshold criteria, then it will not be divided any further. In the event it does not meet the threshold criteria, it is divided again into four blocks and the threshold criteria is applied to these four blocks again. In this way, the process is repeated until each of the four blocks meets the threshold criteria. It can be seen from Figure 2 that the quad tree depicted represents the entire node of the image. In the case of nodes that cannot satisfy the similarity criteria, they will be grouped into four blocks. The last leaf node represents a constant uniform image block that satisfied the similarity requirement. Figure 2 shows the 8×8 image to the content of the size of 1 pixel starting from the block size of level 0.

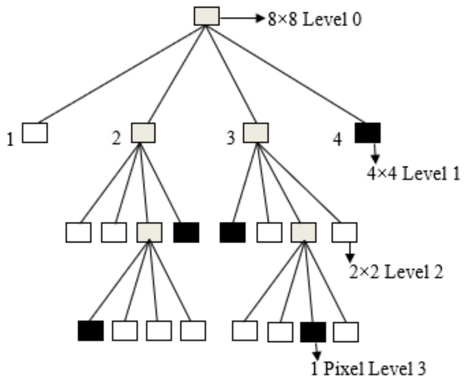


Figure 2. Quadtree 8×8 block and representation of the blocks

Image block is dividing the image set into groups based on some predefined criteria and similarity function. Let I be a set of images to be grouped: $I = \{X_n | \, n = 1, \dots, N\}$. This data is partitioned into a set of groups $U = \{u_g | \, g = 1, \dots, G\}$ Such that $u_g = \{X_{n'} | \, n' = 1, \dots, N'_c\}$ with $u_g \cap u_{g'} = 0$ for all $g \neq g'$ and $U_{g=1}^{g} u_g = 1$. This partitioning should have the property that only similar image is in each group u_g

Several quality measures can be found in the open literature of the image compression. The most commonly used measures is PSNR expressed by;

$$PSNR = 10 \, log_{10}\left(\frac{(Threshold)^2}{\text{CR}}\right)$$

where compressed ratio (CR) is

$$CR = \left(\frac{Threshold \ of \ Compressed \ Image}{Threshold \ of \ Original \ Image}\right)$$

First, the image is resized into 128 × 128 pixels, because it allows better results in experiment tests and reduced the operation time. Then Quadtree method is applied to all blocks. The image is in the size of 128 × 128, of 8 block levels (28-1 = 128). Since the block size is 1 × 1 noise sensitive omitted. Whereas a 128 × 128 block containing the entire image and few images are similar, and calculating a histogram is not considered enough. For other block level histogram is calculated for each level of uniform blocks extracted by Quadtree method. The maximum number of blocks and the block size for all levels are shown in Table 1.

Table 1. Block size and maximum number of blocks for all levels

Block levels	Blocks Size	Number of Blocks	Max number of Blocks
1	128×128	1	16
2	64×64	5	64
3	32×32	25	256
4	16×16	82	1024
5	8×8	167	4096
6	4×4	205	16384
7	2×2	213	65536
8	1×1	28	262144

2.2. Histogram based Compression Algorithmic Setup

The approach is in order where the blocks from a larger image size varies to a smaller size. A real time setup is built to reduce the storage and transmission cost as shown in Figure 3. The setup of the algorithm is illustrated below:

i. *Obtaining the size of the blocks;* $2^{n-1}=N$;

Quadtree method, is divided into two consecutive levels by four equal-size image segmentation.

ii. *If* $u_g \neq$ *Threshold values, then split* $2^{n-1}=N$ *further.*

iii. *If* u_g *= Threshold values,*

iv. *then* u_g *= Histogram end else repeat step ii*

Thus, an image distortion does not occur and data can be reduced slince a sub-block type suitable for the image type is selected from among a plurality of sub-blocks types.

v. *If* $u_{g'} \neq$ *Threshold values, then split* $2^{n-1}=N$ *further again obtained in sept ii*

vi. *Now, pairing is done between highest block and lower block and so on.*

vii. $2^{n-1}=N$ *block and find* $u_g = u_{g'}$ *of the blocks at the level of matching.*

viii. *If* 2^{n-1} *= threshold <* 2^{n-1} *end. else repeat step ii.*

A Quadtree generator for generating a representative value of each block and selective split data that depends on whether or not to perform sequential quad splitting operations on the main block into one type selected among a plurality of sub-blocks according to an image type.

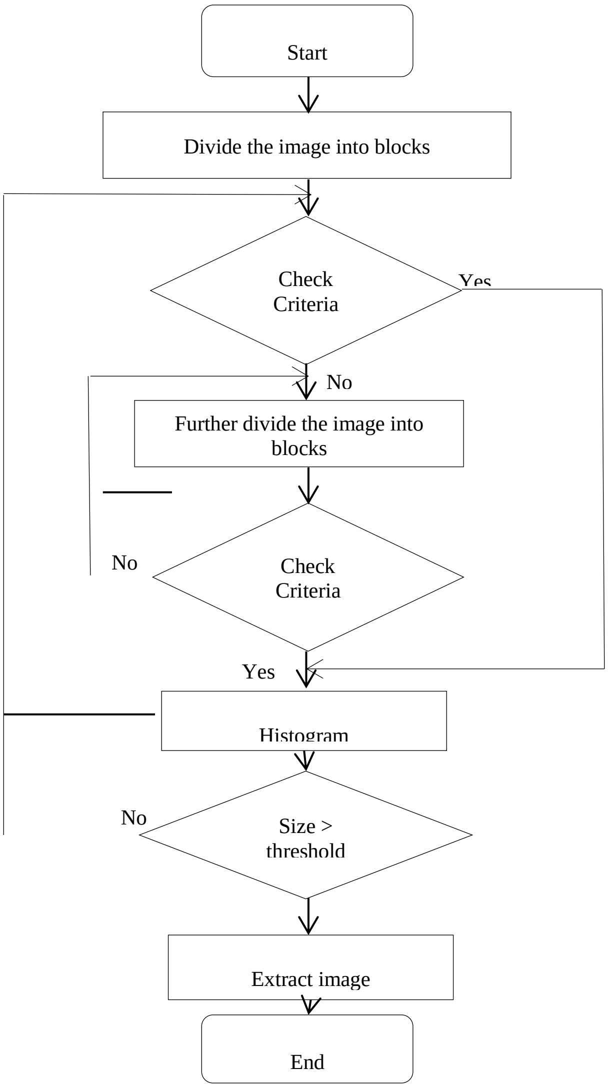


Figure 3 Flow chart of Histogram based compression algorithm

3. Experiment Results and Discussion

Evaluation of the proposed method is simulated a gray level images, including images of the road are shown in Figure 4. The test image is 8 bits / pixel, and the proposed technique was tested on image size of 256 × 256 and 512 × 512 in size. The larger block size for 512 × 512 and 256 × 256 image are 32 × 32 and 16 × 16 pixels respectively. The simulation platform is Microsoft Windows XP, Pentium III, and the proposed approach is implemented using Matlab. The performance of the proposed compression schemes is carried out through the histogram similarity evaulation.

Compression technique is used on the principle of compression, which aims is to maximize the inner space and bandwidth to increase the communication speed. The compression process is completed for different size of image block. The results shown in Figure 4 indicate how the image blocks to be maximized as the image is decayed and shuffling is carried out. Histogram indicates the similarity of the images occurred during the compression process at different level of Quadtree method.

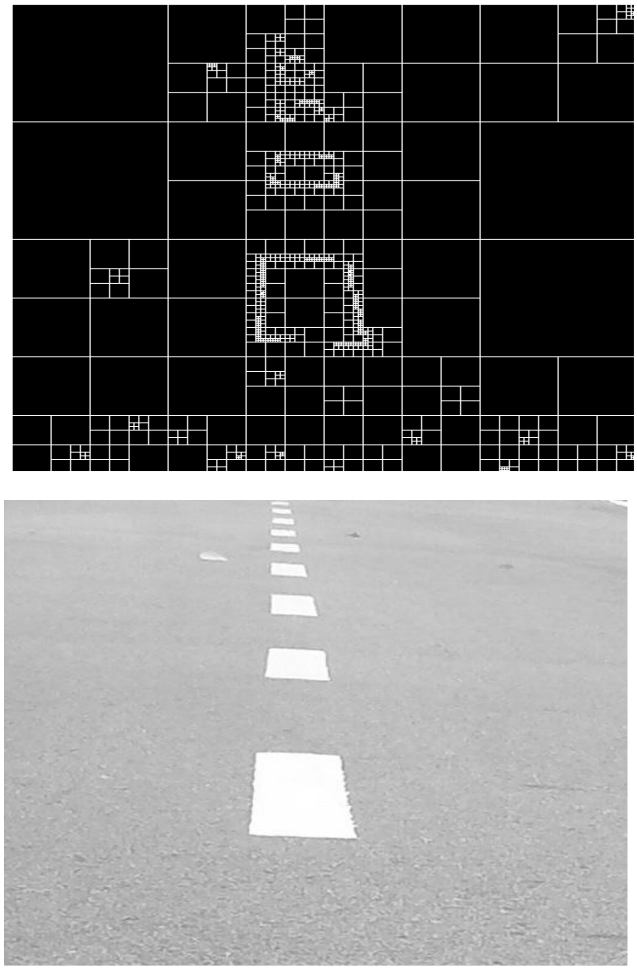
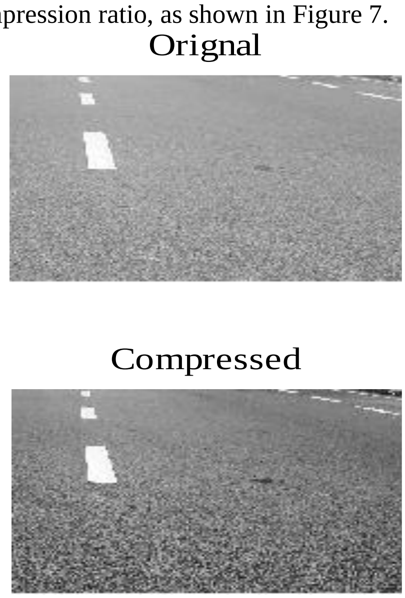


Figure 4 Decomposition and shuffling of an image

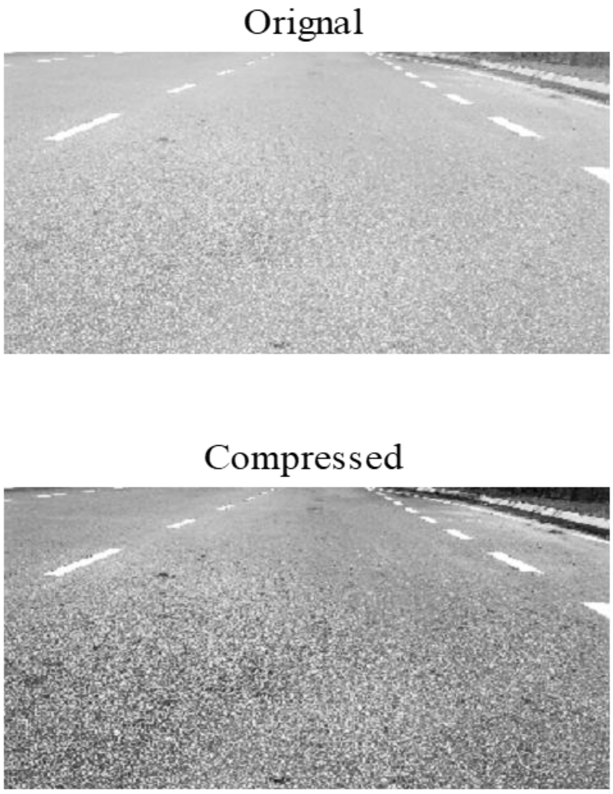
The histogram of the image can be used to measure the difference between the original image and the compressed image by comparing them. In Figure 5, the number of pixels distributed at each intensity level is shown as a representation of how pixels are distributed in the image. Based on the histogram results for this image, we conclude that the block shape is quite consistent with the original image. It is uniformly distributed throughout all possible levels of intensity. Thus, the compressed image provides a trace to encourage original image similarity, as illustrated in Figure 5. A threshold has been applied to the histogram of the image, using the threshold values of 90 and 190. It is worth noting that all magnitudes of all values less than 90 and greater than 190 have been set equal to 0. This results in a uniform gray background in Figure 5. There are large areas of gray background which indicates that there are quite a number of zero values in the threshold compression. After rebuilding the image based on these threshold values, one can obtain the compressed image as a result. It is difficult to detect any difference between the original and compressed images in Figure 5.

Experimental tests have been performed on the road images in order to understand the performance of the algorithm. The tests are conducted for each image using the smallest block size equal to 4, and the threshold values are changed from 90 to 190 with an increment of 10. There is a correlation between the compression ratios and the threshold values, which had an impact on the quality of the compressed image. A compression ratio can be obtained by dividing the threshold value of the compressed histogram by the threshold value of the original image histogram. From the results of the study, it was discovered that the compression ratio ranges from 0.13 to 0.61 as shown in Table 2. The compression ratios tend to increase with the threshold value increasing from 90 to 130, while they tend to decrease uniformly with the threshold value increasing from 130 to 190. For the compression ratio, it has been observed that no matter what threshold value has been set, the compression ratio has been around 0.5. Therefore, it can be concluded from Figure 6 that if we set the threshold value equal to 130, we will get a better compression result.

As shown in Table 2, PSNR is calculated by threshold values using Quadtree algorithm to obtain the PSNR of various images. If the threshold values are increased from 90 to 130, the PSNR decreases much faster. If the threshold values reach the value of 130, which is the threshold value for image compression as discussed earlier, then the PSNR will increase uniformly from one compression ratio to another compression ratio, as shown in Figure 7.



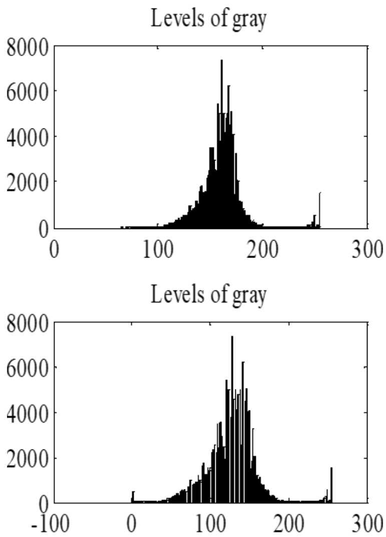
(a)



(b)

Figure 5. Image comparison of different road images based on their histograms

(a)



(b)

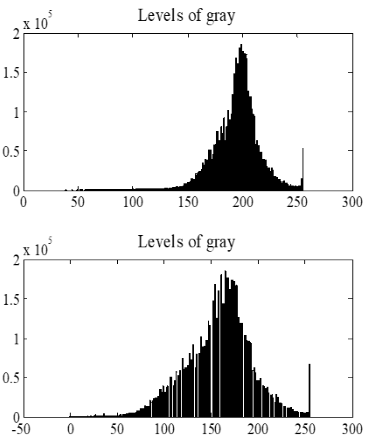


Table 2 Compression ratio and threshold values of different road images with PSNR

Threshold values	Compression Ratio with PSNR							
	Img1	PSNR	Img2	PSNR	Img3	PSNR	Img4	PSNR
90	0.130	49	0.403	48	0.310	48.8	0.380	48.5
100	0.341	47.5	0.551	47.5	0.461	47.46	0.564	47.46
110	0.460	46	0.542	46.5	0.532	46.7	0.591	46.5
120	0.610	45.7	0.534	45.7	0.630	45.8	0.561	45.7
130	0.601	46.3	0.526	46	0.611	46.2	0.554	46.3
140	0.561	46.5	0.501	46.5	0.587	46.5	0.519	46.5
150	0.531	46.6	0.519	46.56	0.582	46.7	0.473	46.6
160	0.481	46.7	0.458	46.57	0.541	46.75	0.440	46.7
180	0.445	46.8	0.389	46.7	0.503	46.8	0.417	46.75
190	0.418	47	0.345	46.8	0.454	46.9	0.404	46.8

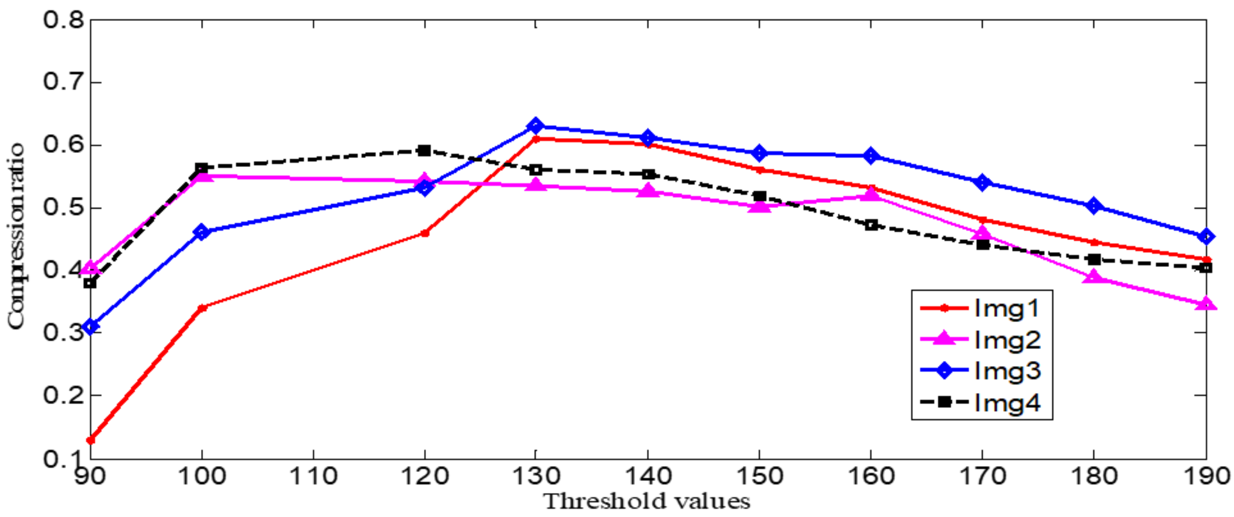


Figure 6 Compression ratio affects by threshold values

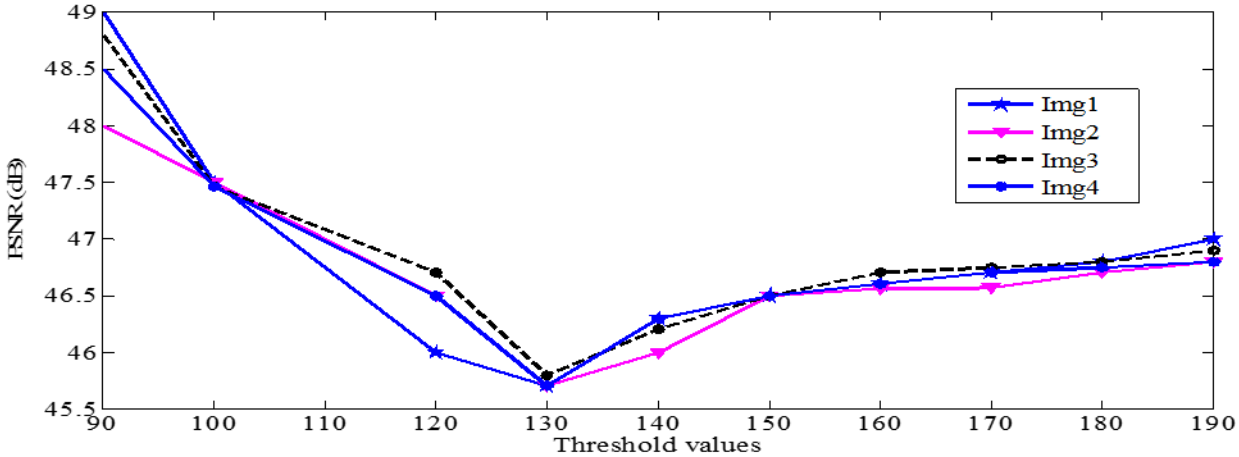


Figure 7 Peak signal noise ratio of different images affected by threshold values

4. Conclusion

A Quadtree algorithm based on histograms can be regarded as an effective method of compressing visual images. In order to be able to find similar blocks of different sizes in the road image, Quadtree compression is applied. The concept of the compressed image block is based on the concept of the information provided by an image block. It is also guaranteed by the proposed method that all the image areas of the image have more or less the same information as the image block. It means that the same level of detail is provided in all parts of the site, and there is not a specific part of the site that displays more information. The results of the experiment tests conducted with different road images provide encouraging results which show the effectiveness of the algorithm.

Acknowledgment: The researchers would like to thank the Deanship of Graduate Studies and Scientific Research at Qassim University for funding support (QU-APC-2025).

Conflicts of Interest: The authors declare that there is no conflict of interest regarding the publication of this paper.

References

[1] Kopylov, Pavel ; Franti, P. Compression of map images by multilayer context tree modeling IEEE Transactions on Image Processing, 2005, 14(1),1 – 11.

[2] Khan, K., Khan, R.U., Albattah, W., Nayab, D., Qamar, A.M., Habib, S. and Islam, M., 2021. Crowd Counting Using End-to-End Semantic Image Segmentation. Electronics, 10(11), p.1293..

[3] Ullah, R., Hayat, H., Siddiqui, A.A., Siddiqui, U.A., Khan, J., Ullah, F., Hassan, S., Hasan, L., Albattah, W., Islam, M. and Karami, G.M., 2022. A Real-Time Framework for Human Face Detection and Recognition in CCTV Images. Mathematical Problems in Engineering, 2022.

[4] Hsin, C. H., Yun, T. S. Image Coding with Adaptive Wavelet Packet Trees, Proceedings of the International MultiConference of Engineers and Computer Scientists, 2008, Hong Kong.

[5] Zhong, J.M. ; Leung, C.H. ; Tang, Y.Y. Image compression based on energy clustering and zero-Quadtree representation, IEE Proceedings Vision, Image and Signal Processing, 2000, 147(6), 564 – 570.

[6] Sasazki, K. Saga, S., Maeda, J. Suzuki, Y. Vector quantization of images with variable block size, Applied Soft Computing, 2008, 8(1), 634-645.

[7] Scholefield, A.; Dragotti, P. L. Quadtree Structured Image Approximation for Denoising and Interpolation, IEEE Transactions on Image Processing, 2014, 23(3), 1226 – 1239.

[8] Alturki, A.S., Islam, M., Alsharekh, M.F., Almanee, M.S. and Ibrahim, A.H., Date Fruits Grading and Sorting Classification Algorithm Using Colors and Shape Features. International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 13, Number 8 (2020), pp. 1917-1920

[9] Morvan, Y., Farin, D., de With, P. H. N. Depth-Image compression based on an RD optimized Quadtree decomposition for the transmission of multiview images, IEEE International Conference on Image Processing, 2007, 105-108.

[10] Marpe, D.; Schwarz, H.; Bosse, S.; Bross, B.; Helle, P.; Hinz, T.; Kirchhoffer, H.; Lakshman, H.; Tung N.; Oudin, S.; Siekmann, M.; Sühring, K.; Winken, M.; Wiegand, T. Video Compression Using Nested Quadtree Structures, Leaf Merging, and Improved Techniques for Motion Representation and Entropy Coding, IEEE Transactions on Circuits and Systems for Video Technology, 2010, 20(12), 1676 – 1687.

[11] Jamzad, M., Yaghmaee, F. Achieving Higher Stability In Watermarking According To Image Complexity, International Journals Of Science & Technology (Scientia Iranica), 2005, 13(4), 404-412.

[12] Tasdoken, S.; Cuhadar, A. Quadtree-based multiregion multiquality image coding, IEEE Signal Processing Letters, 2004, 11(1), 101 – 103.

[13] Tseng, S.Y., Yang, Z. Y., Huang, W., Liu, C., Lin, Y. Object feature extraction for Image Retrieval based on Quadtree segmented Blocks, World Congress on Computer Science and Information Engineering, 2009, 6, 401-405.

[14] Li, S.; Moon, C. L., Chi, M. P. Complex Zernike Moments Features for Shape-Based Image Retrieval, IEEE Transactions on Systems, Man and Cybernetics, 2009, 39(1), 227 - 237

[15] Hui, H. H.; Wei, H.; Zhigang, L.; Weirong, C.; Qingquan, Q. Content-based color image retrieval via lifting scheme, Proceedings on Autonomous Decentralized Systems, 2005, 378 – 383

[16] Kyoung-Mi L., Street, W. N. Cluster-driven refinement for content-based digital image retrieval, IEEE Transactions on Multimedia, 2004, 6(6), 817 – 827.

[17] Laaksonen, J.; Koskela, M.; Oja, E. PicSOM-self-organizing image retrieval with MPEG-7 content descriptors, IEEE Transactions on Neural Networks, 2002, 13(4) 841 – 853.

[18] Markas, T., Reif, J. Quad tree structures for image compression application, Information processing & Management, 1992, 28(6), 707-721