Available online at www.qu.edu.iq/journalcm
JOURNAL OF AL-QADISIYAH FOR COMPUTER SCIENCE AND MATHEMATICS
ISSN:2521-3504(online) ISSN:2074-0204(print)

Image Compression using Polynomial Coding Techniques: A review

Noor S. Mahdi [a], ***Ghadah AL-Khafaji*** [b,*]

[a]*Department of Computer Science, College of Science, University of Baghdad, Baghdad, Iraq. Email: nour.sabbah1201a@sc.uobaghdad.edu.iq*

[b]*Department of Computer Science, College of Science, University of Baghdad, Baghdad, Iraq. Email: ghada.toma@sc.uobaghdad.edu.iq*

ARTICLE INFO

Article history:
Received: 04 /05/2022
Rrevised form: 17 /06/2022
Accepted : 26 /06/2022
Available online: 06 /07/2022

Keywords:

Image compression

Linear/non-linear Polynomial,

Lossy/lossless Polynomial,

Coefficients/residual,

and 1-D linear polynomial.

ABSTRACT

Compression solves the two serious issues of size and transmission efficiently, and various standard techniques are available, such as GIF, JPEG, MPEG, and MP3, in which these techniques combine efficiency, ease of use, and speed with the ability to fulfill a variety of requirements, but there's always a necessity and demand for new innovative techniques to improve the digital realm. Polynomial coding is one of the simple promising compression techniques of modeling base that composed of deterministic part (coefficients) and probabilistic part (residual) to represent image information compactly, there are many models were developed to improve the discipline of this technique performance, where This paper review focused on researchers' efforts to compress grayscale and color images using linear and non-linear lossless and lossy techniques.

MSC..

https://doi.org/ 10.29304/jqcm.2022.14.2.968

1. Introduction

Today, the online presence of people in instant messaging (e.g., Viber, WhatsApp), e-learning (e.g., Google Classroom, Blackboard Learn, Edmodo) and social media (e.g., Facebook, Twitter, Instagram) has become essential, especially with COVID 19 and the immense revolution in computers, mobile phone technology, and communication, where the backbone of this communication is the image [1], which unfortunately comes with a large size in bytes exhausted due to redundancy overburden.

Image data redundancy is at the heart of image compression, with techniques varying depending on how redundancy is removed, with lossless techniques, also known as information-preserving

*Corresponding author: Noor S. Mahdi

Email addresses: *nour.sabbah1201a@sc.uobaghdad.edu.iq*

Communicated by ‘sub etitor’

or error-free techniques, relying solely on statistical redundancy without losing any information, and lossy techniques relying on psycho-visual redundancy, either alone or in combination with statistical re-encoding. The statistical redundancy is dependent on the image type, with two categories (interpixel (spatial), and coding) for gray images and three types (spectral, interpixel, and coding) for color images [2-4]. Figure (1) illustrates the main redundancy types present in images with compression classification techniques. Currently, vast compression techniques available of lossless or lossy base that either standard or non-standard technique, such as Huffman coding, Arithmetic coding and Lempel-Ziv, vector quantization, fractal, block truncation coding, predictive coding, polynomial coding, JPEG, and JPEG 2000, reviews of image compression techniques can be found in [5-14].

Polynomial coding is one of the modern non-standard techniques based on modelling concepts to remove the spatial (interpixel) redundancy embedded within the image pixels effectively [15]. It is based on the use of a mathematical model to represent each nonoverlapping partitioning block with a small number of low-error coefficients (residual), which is characterized by its simplicity, symmetry, and efficiency as a spatial base technique but still suffers from the large number of coefficients and large size of residual [17].

The polynomial coding techniques are generally classified into linear and non-linear according to the approximation degree of the Taylor series, where the former implies the first expansion of the linear base, while the former implies the second expansion of the non-linear base [16] [17]. A number of researchers have exploited these techniques to compress images of lossless or lossy base and/or gray or color base along linear or non-linear schemes. A review of polynomial image compression techniques can be seen in [18]. This paper reviews the efforts implemented to compress images using polynomial coding techniques of either lossless or lossy basis for gray or color images.

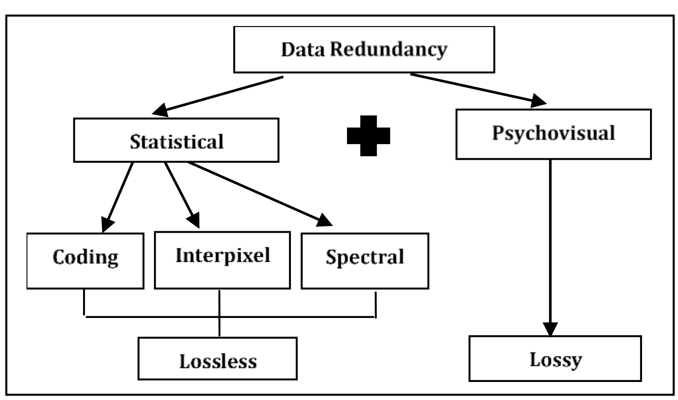

Figure (1) Main Redundancy Types.

2. Literature survey

Polynomial coding is one of the spatial modelling techniques still under development, basically utilized a mathematical model of Taylor series expansion to represent an image value using a deterministic part (coefficients) and probabilistic part (residual), here this survey categorized the polynomial work into lossless and lossy techniques as shown in figure 2, also tables (1) & (2) summarizes the lossless/loss polynomial techniques.

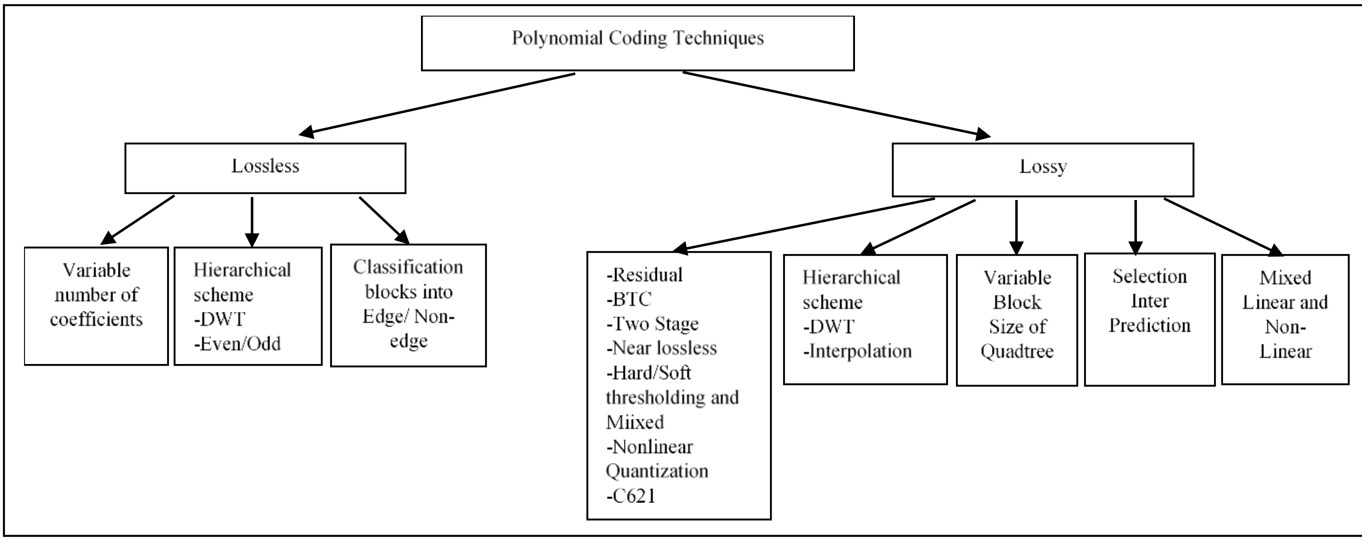

Figure (2) Category in Polynomial of Lossless and Lossy Techniques.

2.1. Lossless polynomial coding:

Ghadah and Loay [19] (2013): suggested a lossless compression system of medical gray scale images using the linear polynomial coding techniques that efficiently exploits the probabilistic part (coefficients) according to block nature, namely the number of coefficients varies depending on whether the block is smooth or not, whereas for smooth one uses only one coefficient of a0, while for non-smooth blocks use the coefficients (a0, a1, a2) using the mean threshold value of each block. The system was tested on eight standard grayscale medical images of MRI and X-ray types of square sizes (256x256/200x200/120x120/512x512) using block sizes of 4x4 and 8x8, where the compression ratio was between 5-6 on average for the former block size, while between 6-8 for the latter block size.

Ghadah and Haider [20] (2013): proposed a lossless hybrid compression system of two level DWT Haar base that decomposed the image hierarchically, where the details sub bands of the two layers coded using the mixed between run length coding (RLC) and Huffman coding techniques, while the approximation sub band of the second layer (LL2) coded using the traditional linear polynomial coding. The suggested system was evaluated using eight standard grayscale medical images of X-ray and MRI types of two square sizes (256x256/512x512), with block sizes of 4x4 and 8x8, the compression ratio was between 7 to 10 on average for the mentioned block sizes, respectively.

Ghadah [21] (2014): suggested a lossless hybrid compression system of multi-DWT and linear polynomial coding, where the partitioned fixed blocks are classified into either edge or non-edge blocks, where for edge blocks use mean values, while for non-edge blocks use DWT of Haar base, then for the approximation sub band use linear polynomial coding, with coding the details of sub bands losslessly. The tested performance adopted four medical grayscale images of MRI and US bases of square size 256x256, with a number of edge pixels between 2 to 10, and a compression ratio between 5 to 9 on average.

Abdullah [22] (2018): presented a lossless compression system to compress natural and medical images using a hierarchal decomposition on an even-odd basis for coefficients and residual images of a two-level scheme. The suggested system results were examined using three standard grayscale square images (Lena, Rose, and MRI Brain) of size 256x256 pixels, with block sizes of 4x4, the compression ratio for natural images is between 7 to 8, while for medical images it exceeds 10.

2.2. Lossy polynomial coding:

Ghadah [23] (2013): utilized a lossy compression system of natural gray scale images using linear polynomial coding with a quadtree partitioning scheme instead of a fixed one, where variable block sizes are adopted depending on the region uniformity, in other words for large uniform regions (i.e., 16x4), use the same number of coefficients (a0, a1, a2) as for non-uniform regions (i.e., 4x2). The system was evaluated using three standard grayscale images (Lena, Living Room, and Pepper) of sizes 256x256 pixels, using quantization levels 4 to 64, with a minimum block size of 2 and a maximum block size of 16, and a compression ratio between 2 to 6 on average, with Normalized Root Mean Square Error (NRMSE) between 0.008 and 0.22 on average.

Ghadah [24] (2013): adopted a lossy spatial compression system of natural grayscale images of mixture of linear polynomial coding and block truncation coding (BTC) to quantize the residual efficiently. The system was tested on four standard images (Lena, Cameraman, Pepper, and Rose) of size 256x256, using block sizes of 4x4 for polynomial coding and BTC, with a compression ratio exceeding 8 to 10, with a Normalized Root Mean Square Error (NRMSE) from 0.08 to 0.1 on average.

Athraa [25] (2015): used a multi-resolution lossy compression system of nearest neighbor interpolation of two layers scheme and linear polynomial coding to compress grayscale images efficiently. The system was tested using two standard natural square images (Lena and Rose) of size 256x256 pixels, using block size 4x4, quantization step for coefficients (a0, a1, a2) equals 1,1,1, and quantization step for residual between 2 to 50, the compression ratio between 3 to 9, with peak signal-to-noise ratio (PSNR) values between 32dB to 52dB on average.

Rasha [17] (2015): introduced a mixture polynomial coding technique on a linear and non-linear basis, using four mixed methods of edge, neighbors, residual, and uniformity to compress lossy grayscale images. The tested results utilized four natural gray scale standard images (Lena, Rose, Pepper, and Cameraman) of size 256x256 pixels, using block sizes of 4x4 with different thresholding values according to the method used, where compression ratio is between 8 to 13, with peak signal-to-noise ratio (PSNR) values exceeding 32 dB.

The use of hard/soft thresholding techniques of hierarchical scheme DWT Haar base to compress residual image of linear polynomial coding techniques adopted by Noor [26] (2015) to compress gray scale images then the same principle extended to compress color images by Ghadah et al [27] (2016). Where the former used scalar uniform quantizer for approximation sub band (LL) with values between 2 to10, along hard/soft thresholding for details sub bands (LH, HL, HH) with values between 20 to 40 and two standard grayscale square images (Lena and Woman) of sizes 256x256, the compression ratio of hard thresholding double the soft one but with less quality compared to soft that characterized by highly preserving quality. While the latter mixed between hard/soft thresholding to compress color bands of RGB base, where the details sub bands of red color band quantized using the soft thresholding, while the other color bands (Green/Blue) quantized using the hard one with utilizing the scalar uniform quantizer of approximation sub bands of all color bands, the tested performance adopted two standard color images (Lena, Girl) of size 256x256 pixels, with scalar quantizer values 5-60, along hard/soft thresholding 40-100, the compression ratio between 5 to 12 with peak signal-to-noise ratio (PSNR) values between 28dB to 30dB on average.

Shymaa [28] (2016): presented a near-lossless scheme to compress grayscale images of a hybrid system of linear polynomial coding and multi-resolution of Haar DWT, where the details of sub bands are quantized hardly. The experimental results were tested on three grayscale standard images (Lena, Pepper, and Cameraman) of square sizes of 256x256 pixels, with error tolerance between 0 to 2, the compression ratio between 9 to 11, with peak signal-to-noise ratio (PSNR) values exceeding 39dB.

Sarah [29] (2016): utilized two-stage multiple description scalar quantizer (TSMDSQ) to quantize the residual images of linear and non-linear polynomial coding techniques to compress gray images. The system was tested using two standard grayscale square images (Lena and Rose) of size 256x256 pixels, with 4x4 block sizes for two models, along with quantization steps for coefficients of 1,2,2 for the linear model, 1,2,3,3,5,5 for the non-linear one, and a quantization step for residual equals 20, the compression ratio for the non-linear model exceeds two times compared to the traditional system, with less than one time for the linear model, and peak signal-to-noise ratio (PSNR) values exceeds 35db to both models.

Ghadah [30] (2018): exploited the midtread quantization scheme to compress the residual of a linear polynomial model efficiently, where the gray scale image was decomposed hierarchically using Haar DWT at one level base, then the details of the sub bands were quantized using soft thresholding while applying the linear polynomial coding for the approximation sub band. The system was evaluated using three standard grayscale square images (Lena, Rose, and Pepper) of size 256x256 pixels, with block sizes of 4x4, quantization step for coefficients 1,2,2, soft thresholding values between 21 to 32, along seven levels midtread base, the compression ratio exceeds 11 with peak signal-to-noise ratio (PSNR)values of 36 or more on average for the three test images.

Marwa [31] (2018): proposed lossy color system compression of mixture between linear polynomial coding and inter-prediction of color bands of RGB base that used the source (reference) band along the seed values to predicted the other non-source bands, where the residual quantized uniformly. The system was tested on three color standards: natural and medical square images (Lena, Girl, and MRI Tummy) of size 256x256 pixels, with block sizes of 4x4, the quantization step of residual images between 5 to 70, the compression ratio on average about 12, with peak signal-to-noise ratio (PSNR)values of 38 dB or more.
Murooj [32] (2018): suggested a lossy compression system of selective residual based on a linear polynomial model, the system utilized nine fixed predictors models, then constructed the selective residual image with the lowest error block values (block by block), where the block with the lowest minimum error is selected, followed by applying linear polynomial coding. The experimental test results used three standard grayscale square images (Lena, Cameraman, and Rose) with sizes of 256x256, block sizes of 4x4, and quantization steps of 1,2,2 and 20 for coefficients and residuals, respectively, with compression ratio four times the traditional linear polynomial model and twice on average to the fixed prediction, with quality exceeding 30 dB.

Ghadah & Anhar [33] (2019): proposed mixed lossless-lossy compression system of medical grayscale images based on an efficient segmentation process along with lossless linear polynomial coding for ROI and scalar uniform quantization for non-ROI, where two segmentation techniques are adopted for stationary and non-stationary background. The system tested on three standard grayscale MRI images of sizes 256x256 pixels, with block size equals 4x4, quantization step for background equal to 2, the compression ratio improved twice to three times on average compared to traditional linear polynomial according to image characteristics, with high peak signal-to-noise ratio (PSNR)quality.

Hawraa [34] (2019): used hybrid techniques to compress color images of Haar DWT of one layer decomposition, where the details of sub bands for each color band were quantized hardly, while the approximation sub bands for all color bands utilized linear polynomial coding of inter-differentiation techniques. To evaluate the performance, three standard color square images (Lena, Girl, and House) of size 256x256 pixels, with block sizes of 4x4, the quantization step for coefficients equals 1,2,2, hard thresholding equals 10-20, quantization of residual 5-50, and the compression ratio between 9-12, with peak signal-to-noise ratio (PSNR)values between 35-30 on average.

Ola [35] (2020): introducing two modeling schemes for linear polynomial coefficients (a0, a1, a2) to compress color images lossily of RGB base, where the first scheme models a0 (mean) jointly for all color bands and the second model all the coefficients differently. The system was tested on three standard color square images (Lena, Girl, and House) of size

256x256 pixels, with block sizes of 4x4, with 1,2,2 corresponding to quantization steps for coefficients and 10,20,30 quantization steps for residual of color images respectively. The compression ratio converged to twice times than the traditional lossy color one for all coefficients model, while less than one for a0 modeling, with peak signal-to-noise ratio (PSNR)values around 30 dB on average.

Ghadah & Loay [1] (2021): introduced 1D linear polynomial coding techniques that reduced the number of coefficients to only two (a0, a1) for each segmented block instead of three coefficients for the traditional one, along with exploiting the non-uniform scalar quantization scheme to quantize the residual effectively. The tested results were evaluated using six images of medical and natural types of sizes 256x256 pixels, with block sizes of 4x4, along with quantization steps from 4 to 32, the compression ratio between 5 to 9, and peak signal-to-noise ratio (PSNR)values between 35 dB to 38 dB.

Samara et al. [36]: exploited the 1-D linear polynomial model with incorporating the matrix minimization scheme of values with five keys randomly generated of sequential search algorithm that is referred to as C621. The system was tested using the same test images adopted by Ghadah & loay [1], with superior performances compared to the mentioned paper, where compression ratios were between 9 to 11, with peak signal-to-noise ratio (PSNR)values between 39 dB to 40dB.

Table 1 – SUMMARIZED POLYNOMIAL CODING OF LOSSLESS BASE RESEARCH WORK

No.	Author	Techniques used	Results
1	Ghadah& loay[19]	Classify blocks according to block nature followed by variable number coefficients of linear polynomial model	Reduced the number of coefficients for smooth blocks compared to non-smooth one with an acceptable compression ratio of between 5-6 for the former block size of lossless base techniques.
2	Ghadah&Haider [20]	Mixed between DWT and polynomial coding along efficient entropy coding	Hierarchal scheme exploits the approximation sub band with polynomial coding instead of the whole image with a compression ratio of between 7 to 10 on average
3	Ghadah [21]	Classify blocks into edge and non-edge block each compressed differently	Improved the compression performance using the multi-wavelet scheme
4	Abdullah [22]	Hierarchal scheme of even/odd utilized for probabilistic and deterministic parts	Higher compression ratio is achieved between 7 to 8 for natural images and exceeds 10 for medical images with identical

			reconstructed image.

Table 2 – SUMMARIZED POLYNOMIAL CODING OF LOSSY BASE RESEARCH WORK

No.	Author	Techniques used	Results
1	Ghadah [23]	Region partitioned hieratically according to region uniformity with variable region sizes	Reduced the number of coefficients for uniform regions compared to non-uniform one with acceptable performance in terms of compression ratio and NRMSE.
2	Ghadah [24]	Quantize residual image efficiently using BTC	Improved compression performance with preserved quality when compression ratio exceeded 8 to 10 and (NRMSE) averaged 0.08 to 0.1
3	Athraa [25]	Nearest neighbor interpolation of two layers scheme base	Reached three-to-four-time compression performance compared to traditional polynomial coding with preserving high image quality.
4	Rasha [17]	Mixed between linear and non-linear polynomial coding techniques	Utilized linear or non-linear models according to block nature where compression ratio is between 8 - 13, with PSNR values exceeding 32 dB.
5	Noor [26] and Ghadah et al [27]	Hard/soft thresholding utilized to compress details sub bands for gray and color images	Residual image in gray or color base compressed using DWT hard/soft thresholding with efficient utilization of the frequency domain along with mixing thresholding techniques where the compression ratio for color images is between 5-12 with PSNR values between 28dB to 30dB.
6	Shymaa [28]	Near lossless scheme adopted to compress residual efficiently	Enhanced compression performance between 9 -11 with pleasing visual quality.

7	Sarah[29]	Used TSMDSQ to compress residual images for linear and non-linear models	The TSMDSQ provide better compression performance results than the traditional models
8	Ghadah [30]	Hybrid system of polynomial coding and mixed between soft thresholding and midtread.	Preserved quality with acceptable compression performance that exceeds 11 with PSNR values of 36 or more.
9	Marwa [31]	Mixed between linear polynomial coding and inter-prediction color bands	The proposed system suitable for compressing medical and natural color images in terms of compression ratio and quality
10	Murooj [32]	Selective residual image constructed using 9 fixed predictor models	Simple preprocessing steps of selective selection improved compression performances by four times when compared to the traditional linear polynomial model.
11	Ghadah & Anhar [33]	Isolate ROI from non-ROI that mixed between linear polynomial coding with scalar uniform quantization	The mixture of lossless and lossy schemes enhanced the compression ratio by twice to three times when compared to traditional linear polynomial with high quality.
12.	Hawraa [34]	Hybrid system of DWT and inter- differentiation for approximation sub band	The suggested system showed success in coding the color image due to reduced image information to quarter of approximation sub band while other details quantized hardly. The compression ratio between 9-12, with PSNR values between 35-30
13.	Ola [35]	Linear polynomial coefficients modeled efficiently	Use two schemes to model the coefficients, with acceptable results in terms of compression ratio and quality.
14.	Ghadah & Loay [1]	Introduced 1-D linear polynomial model with utilizing the non-uniform quantization scheme	High quality is achieved with acceptable compression performance that is between 5-9, and PSNR values between 35 dB-38 dB.

15.	Samara et al. [36]	Incorporate C621 to compress residual of 1-D linear polynomial model	Superior performance of compression ratio between 9 to 11 with and PSNR values between 39 dB-40dB compared to Ghadah & loay[1]

3. Conclusion

This survey is concerned with linear/non-linear polynomial coding techniques as a tool to compress images spatially using the modeling concept of coefficients (deterministic part) and residuals (residual part), where there were many mentioned studies that attempted to enhance the polynomial technique performances using lossless/lossy schemes. This study demonstrates how polynomial coding techniques can be used to improve compression ratio (CR) while preserving image quality with less computation.

References

[1] G. Al-Khafaji and L. E. George, "Grey-Level image compression using 1-d polynomial and hybrid encoding technique," *Journal of Engineering Science and Technology*, vol. 16, no. 6 pp. 4707-4728, 2021.

[2] R. C. Gonzalea and R. E. Woods, *Digital Image Processing*, 2nd Ed. Prentice Hall, 2003.

[3] Y. Q. Shi and H. Sun, *Image and Video Compression for Multimedia Engineering*. CRC Press, London, 2008.

[4] K. Sayood, *Introduction to Data Compression*. 3rd edition. Elsevier Publication, 2009.

[5] G. Al-Khafaji, "*Intra and inter frame compression for video streaming*," PhD thesis, Extraunion, UK. Feb. 2012.

[6] D. Meenakshi, and V. K. Devi, "Literature Review of Image Compression Techniques," *International Journal of Computer Science & Engineering Technology*, vol. 6, no. 5, pp. 286-288, May 2015.

[7] W. Z. Wahba, and A. Y. A. Maghari, "Lossless Image Compression Techniques Comparative Study*," International Research Journal of Engineering and Technology*, vol. 3, pp. 1-9, Feb. 2016.

[8] K. Sharma, and K. Gupta, "Lossless Data Compression Techniques and Their Performance," *International Conference on Computing, Communication and Automation*, 2017, p. 256, doi: 10.1109/CCAA.2017.8229810.

[9] A. K. singh, and A. K. Malviya, "A Survey on Image Compression Methods," *International Journal of Engineering and Computer Science*, vol. 6, no. 5, pp. 21393-21400, May 2017.

[10] S. Arora, and G. Kumar, "Review of Image Compression Techniques," *International Journal of Recent Research Aspects*, vol. 5, pp. 185-188, Mar. 2018.

[11] A. J. Hussain, A. Al-Fayadh, and N. Radi, "Image compression Techniques: A Survey in Lossless and Lossy Algorithms," *Neurocomputing*, vol. 300, pp. 44-69, Jul. 2018.

[12] H. D. Kotha, M. Tummanapally and V. K. Upadhyay, "Review on Lossless Compression Techniques," *International conference on computer vision and machine learning IOP Conf. Series: Conf. Series 1228 (2019) 012007*, 2019, doi:10.1088/1742-6596/1228/1/012007.

[13] S. P. Amandeep Kaur, Sonali Gupta, Lofty Sahi, "COMPREHENSIVE STUDY OF IMAGE

COMPRESSION TECHNIQUES," *Journal Critical Reviewers*, vol. 7, no. 17, pp. 2382–2388, 2020.

[14] A. Gupta, and S. Nigam, "A Review on Different Types of Lossless Data Compression Techniques," *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, vol. 7, no. 1, pp. 50-56, 2021.

[15] G. Al-Khafaji, and H. H. Razzaq, "Extended Hierarchal Polynomial Coding and Fixed Predictor of Lossless Base," *International Journal of Research in Computer Applications and Robotics*, vol. 7, no. 7, pp. 7-13, Jul. 2019.

[16] G. Al-Khafaji, and L. E. George," Image Compression based on Non-Linear polynomial prediction Model*," International Journal of Computer Science and Mobile Computing*, vol. 4, no. 8, pp.91-97, Aug. 2015.

[17] R. Al-Tamimi, "*Intra Frame Compression Using Adaptive Polynomial Coding*," MSc. thesis, Baghdad University, Collage of Science, Iraq. 2015.

[18] S. S. AL- Hadithy, G. Al-Khafaji, "Polynomial Image Compression: A Review," *1st International Conference Pure Science (ICPS-2021) in College of Science / University of Diyala, Iraq, by AIP Conference Proceeding (ISSN: 0094-243X),* 2021.

[19] G. Al-Khafaji, and L. E. George, "Fast Lossless Compression of Medical Images based on Polynomial," *International Journal of Computer Application*, vol. 70, no. 15, pp. 28-32, May 2013.

[20] G. Al-Khafaji, and H. Al-Mahmood, "Lossless Compression of Medical Images using Multiresolution Polynomial Approximation Model," *International Journal of Computer Application*, vol.76, no. 3, pp. 38-42, Aug. 2013.

[21] G. Al-Khafaji, "Wavelet transform and polynomial approximation model for lossless medical image compression," *International Journal of Advanced Research Computer Science and Software Engineering,* vol. 4, pp. 584-587, 2014.

[22] A. Abdulhussain, "*Hierarchal Polynomial Coding of Grayscale Lossless Image Compression*," Higher Diploma, University of Baghdad, Collage of Science, Iraq. Jan. 2018.

[23] G. Al-Khafaji, "Image Compression based on Quadtree and Polynomial," *International Journal of Computer Application*, vol. 76, no. 3, pp. 31-37, Aug. 2013.

[24] G. Al-Khafaji, "Hybrid Compression based on Polynomial and Block Truncation Coding," *Electrical, Communication, Computer, Power, and Control Engineering (ICECCPCE), International Conference on Mosul, IEEE,* 2013, p. 179.

[25] A. T. Khudhair, "*Adaptive Polynomial Image Compression*," Higher Diploma, University of Baghdad, Collage of Science, Iraq. Jan. 2015.

[26] N. S. Mahdi, "*Image Compression based on Adaptive Polynomial Coding*," Higher Diploma, University of Baghdad, Collage of Science, Iraq. 2015.

[27] G. Al-Khafaji, N. S. Mahdi, U. Al-Hassani, "Hybrid Color Image Compression of Hard &Soft Mixed Thresholding Techniques," *International Journal of Computer Science and Mobile Computing,* vol. 5, no. 7, pp. 375-381, Jul. 2016.

[28] Sh. Fadhil, "*The Use of Haar Wavelet a Polynomial coding for Compressing Grayscale Image*," Higher Diploma, University of Baghdad, Collage of Science, Iraq. 2017.

[29] Sara A. Abdulrahman "*Linear Polynomial Coding with Two Stage Multiple Description Scalar Quantization*," Higher Diploma, University of Baghdad, Collage of Science, Iraq. 2016.

[30] G. Al-Khafaji, "Linear Polynomial Coding with Midtread Adaptive Quantizer," *Iraqi Journal of Science*, vol. 59, no.1c, pp. 585-590, 2018.

[31] M. Al—Obaidi. "*Color Image Compression by using Inter Prediction Base*," Higher Diploma, University of Baghdad, Collage of Science, Iraq. 2018.

[32] M. A. Dagher, "*Fixed and Selective Predictor Polynomial Coding for Image Compression*," Higher Diploma, University of Baghdad, Collage of Science, Iraq. 2018.

[33] G. Al-Khafaji, and A. Sami, "Medical Image Compression based on Polynomial Coding and Region of Interest," *Al-Hussain Bin Talal University Journal of Research, in 2nd conference for Engineering and Science*, 25-27 Nov. 2018, Turkey, paper 1, p. 48.

[34] H. B. AL-Kazaz, "*Adaptive Color Image Compression of Polynomial based Techniques*," Higher Diploma, University of Baghdad, Collage of Science, Iraq. 2019.

[35] O. K. Obayes, "*Polynomial Color Image Compression using Joint and Different Models*," Higher Diploma, University of Baghdad, Collage of Science, Iraq. 2020.

[36] S. S. AL- Hadithy, G. Al-Khafaji, M. M. Siddeq, "Adaptive 1-D Polynomial Coding of C621 Base for Image Compression," *Turkish Journal of Computer and Mathematics Education,* vol. 12, no. 13, pp. 5720-5731, 2021.