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Pixel Based Techniques for Gray Image Compression: A review

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ABSTRACT

Currently, with the huge increase in modern communication and network applications, the speed of transformation and storing data in compact forms are pressing issues. Daily an enormous amount of images are stored and shared among people every moment, especially in the social media realm, but unfortunately, even with these marvelous applications, the limited size of sent data is still the main restriction's, where essentially all these applications utilized the well-known Joint Photographic Experts Group (JPEG) standard techniques, in the same way, the need for construction of universally accepted standard compression systems urgently required to play a key role in the immense revolution.

This review is concerned with Differential pulse code modulation (DPCM) and pixel-based techniques, where the spatial domain is exploited to compress images efficiently in terms of compression performance and preserving quality. The new pixel-based method overcomes predictive coding constraints with fewer residues and higher compression ratios.

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1. Introduction

Today, Social platforms allow individuals to communicate with each other effortlessly, cheaply and exchange ideas or content immediately, using apparatuses utilizing the savvy phones, tablets, and computers, where the images are the cornerstone, particularly in events (i.e., Eids, Christmas time and Birthdays), news, showcasing, amusement, but unfortunately, these images required huge consumption of bytes, so the compression is the ideal solution to excess expelled proficiently via redundancy removal [1]. Despite the significant development in the capacity of high-quality storage devices and giant communication networks, the demand for pressure algorithms is a critical central issue for maintaining legitimate storage space and less transmission time [2].

Image compression addresses the issue of decreasing the size of image information required without any visual degradation [3]. Compression of gray images base is accomplished by the eliminating one or more of the three data redundancies that are generally classified into statistical and psych visual redundancies [4], where:

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1. Coding redundancy: is statistical redundancy due to the digitization process, where each pixel value is quantized more than the required bits.

2. Interpixel redundancy: is statistical redundancy due to similarity or correlation between neighbors' adjacent pixel values, unless an edge is present.

3. Psych visual redundancy: due to the human visual system (HVS), where the human eye is characterized by limited sensitivity to visual information that leads to loss of insignificant information while preserving the whole details of the image.

The structure of image compression is made up of two main units: an encoder and a decoder. [2], where the former corresponds to redundancy removal (filtration), while the latter resembles a reconstruction (builder) of information after the redundancy is eliminated, where subunits of each basic unit depend on compression type and requirements. Also, pre-processing/post-processing operations may be involved to enhance the system performance [4].

This paper reviews the efforts implemented to compress images that basically concentered on the techniques of pixel-based that implies the DPCM and pixel modeling.

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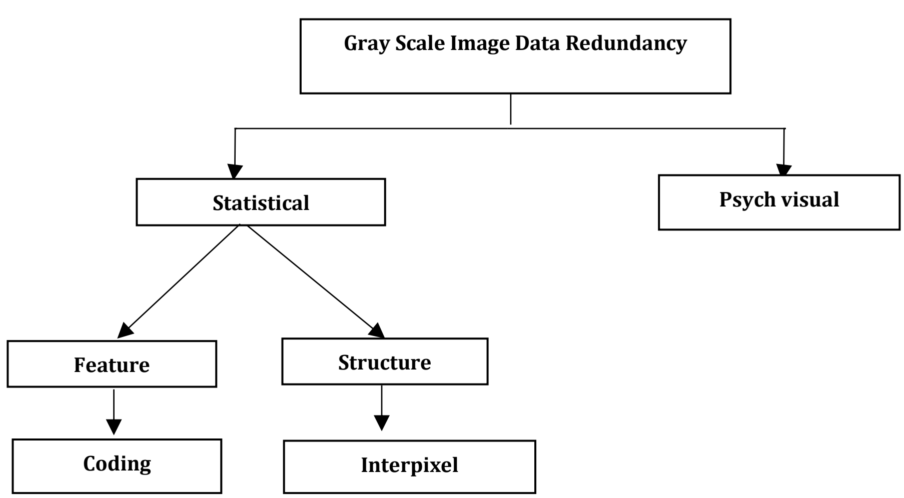
2. Image Compression Techniques

Generally, the compression techniques are classified according to the type(s) of redundancy(s) removal that implies two classes lossless and lossy, where the former utilized the statistical redundancy, while the latter exploited the psych visual redundancy, either solely or combined with statistical redundancy [5], as shown in Figure 1.



Figure(1): Types of image data Redundancy Removal

2.1 Lossless compression

This compression type is also referred error free (reversible, identical compression), where the original image can be identically recovered from the compressed (encoded) image without any loss (degradation), where keeping all the information is prioritized at the expense of compression, namely low compression ratio attained. Usually, lossless techniques are used for critical applications such as medical, military, space programs, and remote-sensing, including Huffman coding, Arithmetic coding, and Lempel-Ziv algorithm [2,5].

2.2.Lossy Compression

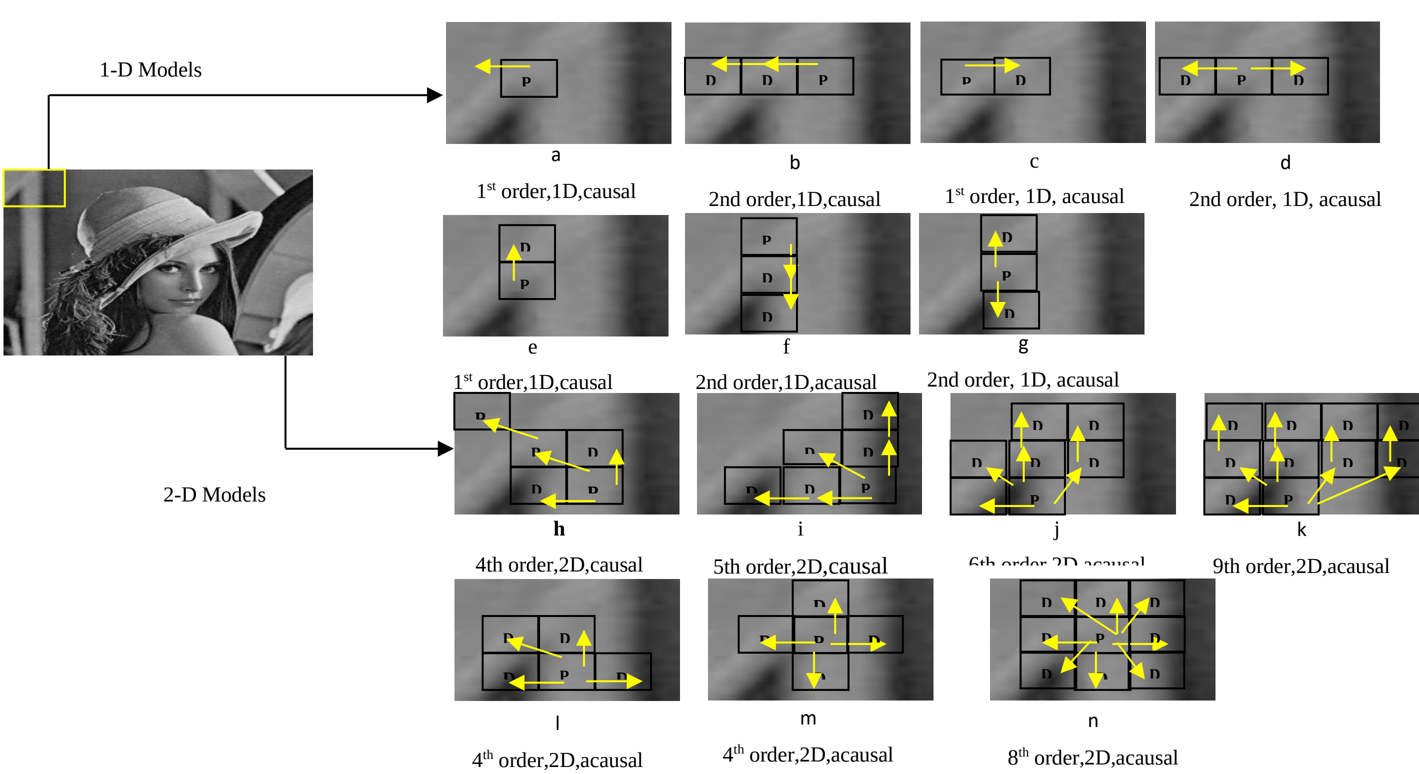
This compression type is also referred irreversible (approximation compression), where the approximated image is recovered from the compressed (encoded) image with loss (degradation), where losing unrecognized information leads to high compression, namely a high compression ratio attained. Usually, lossy techniques are used for daily media applications that imply Television (TV), video, internet, and audio, with techniques such as vector quantization, Block Truncation Coding, fractal (BTC), and JPEG[2,5].

3. Predictive Coding

Predictive coding (PC), also referred to as DPCM or Auto-Regressive (AR) model, is a simple spatial coding technique to remove interpixel embedded between neighborhoods using a modeling scheme (formula) that is implicitly composed of three basic parts. The first part is the order which corresponds to the number of neighbors utilized,

the second part is the structure that either be 1D or 2D, which means using the row or row/column, respectively, and lastly, the third part is the causality that either be causal or acausal which means use the previous or next neighbors (s) [5], Figure 2 shows various PC models.

These techniques are still under development, which suffers from a standardization model where the model complexity varies according to image details, difficulty in estimating coefficients, and huge size of residual that leads to low compression performance [6].



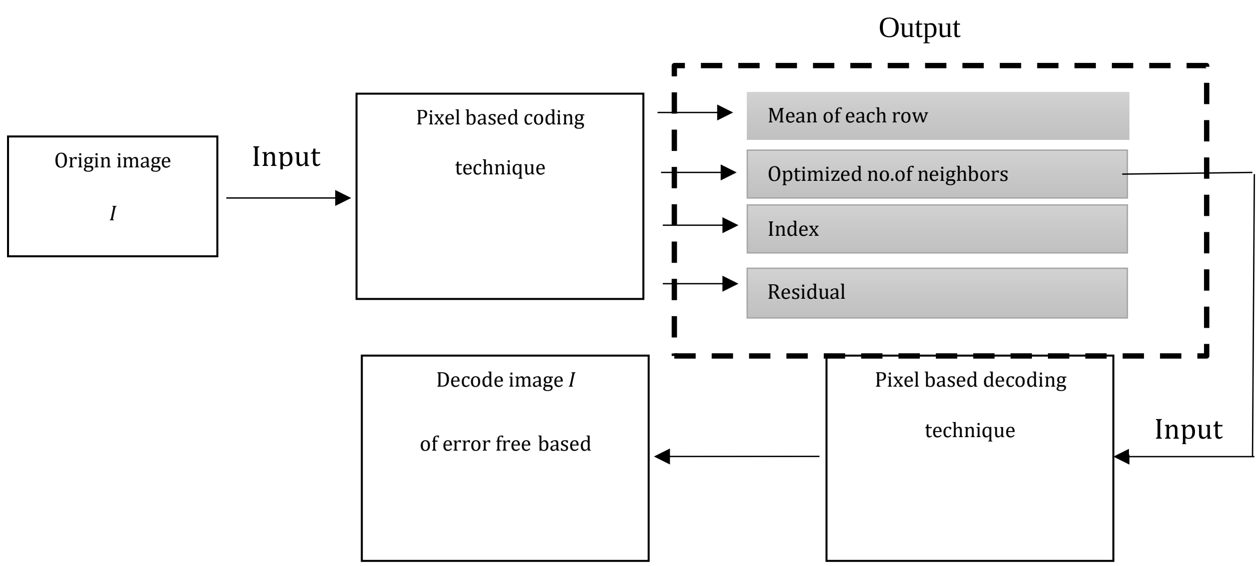
Figure(2): Predictive coding models, where

P corresponds to the predicted pixel, D corresponds to the known

4. Pixel Based Techniques

Pixel-based is a modern spatial coding technique introduced by Abdullah and Ghadah in 2021 [6] to remove interpixel redundancy efficiently using the mean value and try to identify the model of each pixel value corresponding to the best value of minimum residual [7].

This new technique overcomes the predictive coding limitations, where a standard optimized model is utilized, with less residual obtained that directly improves the compression ratio [7]. Figure 3 illustrates the input/output pixel based coding system structure



Figure(3): The input/output pixel based coding system structure

5-Related Work

Reducing the image size becomes an essential interesting subject, where the challenge is to improve new compression system suitable for applications (medical, daily, E-government). This review section concentrates on compression techniques based on modeling concept that impels predictive coding and pixel-based techniques.

1- Haider and Zainab, in 2014 [8], suggested lossy spatial techniques to compress grayscale images by utilizing the combination of bitplane slicing (BPS) and PC, where the image is firstly sliced into eight bits, then the Least Significant Bit (LSB) ignored, while the first three bits of MSB coded using run-length coding (RLC). The later highest bit (bit slice8) of MSB coded using PC of the third order, 2D structure, causal model. The experimental results were tested on eight standard gray images of natural and medical types of square sizes 256x256 pixels, where the Compression Ratio (CR) was between 6 to 8 on average with preserving quality.

2- Ann and cinly in 2015 [9], proposed a lossless color compression system of YCbCr transformation model, where Y compressed hierarchal scheme of even/odd base, while the other color bands CbCr compressed using PC techniques of eight order, and sixth 2D structure a causal models respectively. The tested performance achieved better CR compared to Huffman and arithmetic coding techniques of probability-based.

3-Suresh and Sathappan, in 2015[10], adopted a lossy compression system to compress grayscale images using a hierarchal scheme of even/odd decomposition along with adaptive prediction Modified Hierarchical Prediction and Context Adaptive (MHPCA) of three order, 2D, causal, averaging model. The system was tested on six standard grayscale images, with CR between 1.5 to 4.1 along with quality of Peak Signal-to-Noise Ratio (PSNR)values between 34dB to 28 dB.

4- Abo-Zahhad et al. in 2015 [11], presented a lossy compression system to compress medical grayscale images using a mixture of DPCM, *DISCRETE WAVELET TRANSFORM* (DWT), and Huffman coding of two schemes, where the first one exploited the DPCM, DWT of dubaches/Haar basis followed finally by Huffman coding, while the second one is preceding DWT than DPCM with encoded Huffam coding. The system was evaluated using 10-12 grayscale selected images from U.S. National Library Medicine (NLM) of sizes either 256x256 or 512x512 pixels, where the first scheme archived CR between 227 to 4.32 on average with PSNR between 33.16dB to 30.23, while the second attained CR between 5.33 for dubachies and 6.48 for Haar with PSNR values 30.07dB and 28.81 dB.

5- Rime and kapil, in 2016 [12], suggesting a lossless compression system for grayscale images, where the PC is based on the block based, namely utilizing the modeling for each segmented fixed block region instead of the whole image, then the residual coded using Huffman encoding techniques of probability-based. The experimental results used three standard grayscale images (Lena, Barbara, Baboon) of square sizes 256x256/512x512 pixels, with CR between 7 1o 8 for block sizes equals 4x4 of identical resonstred image base.

6 Ashwaq and Suhad, in 2016[13], introduced a lossy hybrid color image compression system of spatial based techniques (PC), along with transformed based techniques of mixture between DISCRETE COSINE TRANSFORM (DCT) and DWT. The system starts by converting the color image from RGB base to color transformation model of YUV, then each transformed color band utilized PC of 8x8 block-based, according to the amount of residuals of each block of 8x8 size, the maximum absolute value computed, where for correlated blocks that maximum absolute value less than the threshold the DCT adapted, while for non-correlated blocks the DWT utilized, finally both transformed based techniques coded using quadtree and shift coding techniques. The system was evaluated using six standard color images of sizes 256x256/512x512 pixels, with different quantization steps (Q0, Q1, alpha, beta,q1,q2,q3) and thresholding values (Thr) control parameters. The results of PSNR values are extended from 30.62 to 40.95dB and CR on normal, with a reduction of the size of the original image between 1 to 11.6

7- Narmatha, Manimegalai, and Manimurugan in 2017[14] proposed a compression system to compress grayscale image losslessly of pixel-based techniques using separation and shuffling processes that converted into binary values to encode. The experimental results on six standard grayscale square sizes images of 512x512 pixels (256 Kilobyte (KB)), showed reduced in original size by more than a half on average of identical reconstructed image base.

8- Gashnikov in 2017 [15], introduced a lossy compression system of gray base images using different DPCM models with an adaptive extrapolator to preserve the local features of contours (boundary) of optimized based, then the residual quantized uniformly using the MaxScale Scheme. To assess the proficiency of the proposed image compression strategy based on DPCM with the versatile extrapolator, using CR and quantized error "error-compression proportion" adopted on the set of images "Waterloo", where CR between 2.1 to 4.5 with the error between 10 to 140.9, also the results of the experiments demonstrate a significant gain (up to two times) of DPCM with an adaptive extrapolator for the JPEG method with respect to the maximum error.

9- Sharana et al. in 2017[16] utilized the least square method (LSM) to estimate the DPCM coefficients for the lossy compression system of grayscale images. The experimental results were evaluated using Lena standard grayscale square image of size 256x256 pixels, with quantization steps of 2,4,8 levels, respectively. The results showed that the distortion in error (residual) was reduced by 7-8dB compared to traditional DPCM without LSM.

10- Mohamed and Eswaran in 2017[17], introduced a lossy compression system of DPCM and vector quantization (VQ) referred to as PE-VQ, namely utilized VQ to compress prediction error (PE) or residual, where optimum codebook generated using two algorithms of the artificial bee colony and genetic algorithm. The system performance was tested using three different datasets CLEF med 2009, Corel 1 k database, and six standard images, where CR exceeds 10 with high quality values between 50dB to 40dB.

11- Ahasan and Rubaiyat in 2018 [18], presented two lossless compression techniques, the former referred to as ETEC "edge-based change and entropy coding" of only four neighboring pixels, and the latter called PTEC "prediction-based transformation and entropy coding" to overcome the inherited problems of ETEC, that based the hierarchal scheme of even/odd base, followed by encoding the residual error (prediction error) efficiently using a form two matrices, where one matrix contains the absolute error value and the other contains the polarity of the prediction error, lastly/finally coded using Huffman coding/Arithmetic coding respectively. The proposed system was evaluated using various images of varying details (characteristics), and the results were compared with the existing lossless compression techniques: "joint photographic experts group lossless" (JPEG-LS), "set partitioning in hierarchical trees" (SPIHT), and "differential pulse code modulation" (DPCM), with better compression performance of the proposed techniques compared to the other, where PTEC is almost 10.28, JPEG-LS (9.264), SPIHT (3.178), and DPCM (3.09) on average.

12- Mikhail and Alexei, in 2018 [19], suggested a modern parameterized extrapolator that gives expanding the effectiveness of DPCM compression by exchanging between nonlinear and linear expectation strategies for each prepared pixel, namely using four direction contour- invariant extrapolator, where if the difference modulus between the extrapolated averaging and non-linear method is small, the linear model adopted. Otherwise, non-linear model is exploited, followed by incorporating a uniform quantization scheme of maximum error techniques. The system was tested using twelve standard grayscale square images of sizes 256x256, with CR between 1.50 to 2.70 and Root Mean Square Error (RMSE) limited between 0.25 to 1.85.

13- Shankar and Kannammal, in 2018 [20], suggested a lossy medical image compression system of gray base specific for Medical Resonance Imaging (MRI) and Computed Tomography (CT) images of the brain containing the tumor. The proposed system starts by segmentation process that efficiently isolates ROI from non-importance (RONI) using the K-means algorithm; then, each region is compressed differently, where the former is compressed using Curvelet transform and Differential Pulse Code Modulation (DPCM), while the latter coded Wavelet Transform (IWT) followed by Set Partitioning in Hierarchical Tree (SPIHT) and adaptive arithmetic coding. The experimental results were tested using five medical images, the attained CR between 4.3 to 7.8, with PSNR values between 50.2dB to 54.3dB.

14- Azman et al. in 2019 [21], proposed a hybrid lossless grayscale image compression system that combination of DPCM (third order, 2D structure, Casual model) of spatial based techniques along lifting scheme and Haar DWT of frequency-based techniques followed by entropy coding of Huffman coding. The system was tested on five standard grayscale square images of sizes 512x512 pixels, where CR was achieved between 1.025 to 2.046...

15- Eduardo et al. in 2019 [22], exploited two linear prediction models pixel-based to compress grayscale images losslessly using arithmetic coding, where the first model used two prediction forms, one of pixel intensity in Upper-Left neighbor / Upper-Right neighbor (UL/UR), the other one used Upper(U), Left(L), Right(R), Bottom(B) neighbors, while the second model used three prediction forms of one, four neighbors, where the former used the left bottom, the other used either UL, UR, Bottom Left-neighbor (BL), Bottom-Left neighbor (BR) or U,L, R,B. the system evaluated on three common tested images of International Telecommunications Union -Telecommunication Standardization Sector (ITU-T) T.24 dataset of natural, medical, photo text/drawing grayscale either square or non-square images, the

CR of the first model between 1.240 to 4.99, while the second one between 1.244 to 5.650, where results vary according to image complexity of identical resonstred image base...

16- Ghadah and Heba, in 2020 [23], adopted the mixing between hierarchal scheme decomposition of even/odd base along the DPCM with the same model or mixing models to compress medical Magnetic Resonance Imaging (MRI) images losslessly, namely using the same DPCM (fixed predictor) for all quadrants (subbands) or exploited DPCM for each quadrant according to the subband information (details). The proposed system was tested using eight DPCM models (left, bottom, left-bottom, averaging, maximum, minimum, mode, median) with three standard MRI grayscale images of square sizes of 256x256 pixels, where the CR for fixed (same) model vary between 1.5 to 2.7, while with mixing DPCM the CR exceeds 7

17- Abdullah and Ghadah, in 2020[8], introduced new modern pixel-based compression techniques of optimized minimum residual, where the hybrid system adopted along DWT of Haar base and hierarchal quantization scheme to ensure high performance in terms of compression ratio and quality. The system was tested using three standard grayscale square images of sizes 256x256, with a different number of neighbors, increment values, and hierarchal quantization steps values of Q, β,α, where CR exceeds 14 with excellent quality over 41dB.

18- Anitha, Lakshmi, and Rajesh, in 2021[24], utilized intra prediction algorithm of video compression standards to compress grayscale images lossy; the suggested system is based on partitioning the input image into fixed square block sizes from 4x4 up to 32x32 pixels, then for each current block, calculate Block Distortion Measure (BDM) for the 8 neighboring blocks in the square range, if minimum BDM is zero in any of the neighboring blocks, a Predicted block is found, and the residual is created, otherwise, Calculate BDM for the 12 blocks in the octagon range, followed by computed the minimum BDM, finally selected the predicted block with minimum BDM. The experimental results were tested on seven standards grayscale square images of sizes 256x256/512x512 pixels, with average performances equal to 5.6325 and 56.7008dB for CR and PSNR, respectively.

19-Hochang, Yeong, and Nam, in 2021 [25], presented a lossless compression system of color images of YUV color transformation model. Then for each pixel multilayer perceptron (MLP) predicts the pixel using causal neighbors, then the prediction error (residual) coded adaptive arithmetic coder (AAC). Finally, the system may extend to involve classification into smooth and texture patches to overcome computation time. The system was evaluated using three datasets, a classical dataset of twelve popular images (Lena, Barbara, Goldhill) of square sizes of 512x512 pixels, the Flickr2K dataset consisting of 2,650 test images, where 100 images were selected randomly, and DIV2K dataset is also a high-resolution image dataset with diverse contents, with bits per pixel (bpp) equals 2.56 on average, along 108 sec encode time.

6. Studies description

Description of study In this section, table 1 summarizes the image compression techniques that were previously explained and clarified during the subject review.

Table 1 – summary of subject review

no	Author	Compression Technique	Compression Method	Describe
1.	Haider and Zainab	lossy	Bit plane slice	After deleting the lowest order bits and using just the highest order bits in which the most significant bit corresponds to the last layer, layer7 employed adaptive predictive coding, whereas the

				other layers used run-length coding to optimally utilize the spatial domain.
2.	Ann and Cinly	Lossless	hierarchal scheme	Use hierarchical prediction and context-adaptive arithmetic coding for Compressing a color image, and Lower bit rates are obtained compared to JPEG2000 and JPEG-XR.
3.	Suresh and Sathappan	Lossy	MHPCA	MHPCA (Modified Hierarchical Prediction and Context Adaptive) coding is used to solve the problem of large prediction error rates at edges while preserving image sharpness. Bit rates in compressed images are decreased significantly, preserving image sharpness. The MHPCA coding system also has a lower error rate and a higher compression ratio than the current HPCA scheme.
4.	Abo-Zahhad,et al	Lossy	DPCM, Transform coding	The image is first pre-processed using a Differential Pulse Code Modulator (DPCM), then wavelet transformed, and then Huffman encoding is applied to the coefficients.
5.	Rime and kapil	Lossless	DPCM, Huffman	Instead of modeling the entire image, each segmented fixed block region was modeled separately, and the residual coded using Huffman encoding.
6.	Ashwaq and Suhad in 2016	Lossy hybrid	Transform Coding	The DCT was used for correlated blocks with a maximum absolute value smaller than the threshold, while the DWT was used for non-correlated blocks, and both transformed-base approaches were coded using quadtree and shift coding techniques.
7.	Narmatha , Manimegalai and Manimurugan	lossless	DPCM	The use of differential pulse-code modulation (DPCM) with an adaptive extrapolator is investigated, with the original size of identical reconstructed image bases being decreased by more than half on average.
8.	Gashnikov	lossy	DPCM	employing various DPCM models with adaptive extrapolators to maintain the local features of contours (border) of optimal based, then

				quantizing the residual uniformly using the MaxScale Scheme
9.	Reenu, et al	Lossy	DPCM	The DPCM coefficients were estimated using the least square method (LSM), resulting in a reduction in compressed image distortion and estimation error.
10.	Mohamed and Eswaran	Lossy	DPCM , Vector quantization	VQ was used to reduce the prediction error (PE) or residual. A mixture of two algorithms, artificial bee colony and genetic algorithms, is used to build an optimal codebook.
11.	Ahasan and Rubaiyat	Lossless	DPCM	Two algorithms were used for pixelated images, the first algorithm is ETEC and the second is called PTEC, which is a new algorithm based on prediction, and based on the compression ratio and computation time, these two algorithms are compared with the current JPEG-LS SPIHT and DPCM methods
12.	Mikhail and Alexei		DPCM	For differential pulse code modulation (DPCM) image compression, a paramterized four-direction contour-invariant extrapolator is described. Extrapolation can be done using one of two methods: linear or nonlinear. The extrapolation method chosen is dependent on the presence of a contour in the vicinity of each processed pixel.
13.	Shankar and Kannammal	Lossy	DPCM,IWT, arithmetic coding	The K-means method is used to divide the input image into ROI and RONI. The ROI section uses the Curvelet transform and DPCM (Differential Pulse Code Modulation). The RONI portion is encoded using the Integer Wavelet Transform (IWT), Set Partitioning in Hierarchical Tree (SPIHT), and adaptive arithmetic coding.
14.	Azman, et al	hybrid lossless	DPCM	The technologies of DPCM and Haar DWT of frequency are merged, followed by Huffman entropy coding.
15.	Eduardo et al	lossless	arithmetic coding	Linear prediction is used first, followed by arithmetic coding. The algorithm is available in two versions. Algorithm 1 employs two different prediction functions, while Algorithm 2 employs three. Although Algorithm 2 produces somewhat

				better outcomes than Algorithm 1, their performance is relatively similar.
16.	Ghadah and Heba	Lossless	DPCM	Use the same DPCM (fixed predictor) for all quadrants (sub-bands) or use a different DPCM for each quadrant based on the sub-band information.
17.	Abdullah and Ghadah	Hybrid	Haar DWT, hierarchal quantization	To optimize minimum residual, a hybrid system with DWT of Haar base and hierarchal quantization technique was used.
18.	Anitha , Lakshmi and Rajesh	Lossy	Transformation entropy coding	Partitioning the input image into fixed square block sizes from 4x4 up to 32x32 pixels to find the prediction of a current pixel. Instead of the traditional four mode prediction.
19.	Hochang , Yeong and Nam	lossless	Arithmetic coding	Multilayer perceptrons are used to learn pixel values and contexts (MLPs). Adaptive arithmetic encoders receive the prediction errors and contexts obtained by MLPs.

6. Conclusion

This survey is concerned with image compression techniques of the spatial base that implies DPCM and pixel-based schemes, where both based on modeling concepts. There were many mentioned studies that aimed to overcome the inherited problems, especially large residual, which constitutes the major load, due to the limitation of the prediction modeling scheme.

The constraints of predictive coding have been overcome by new pixel-based techniques that use an enhanced standard model. with fewer residues and higher compression ratios than the previous model.

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