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Lossless Biometric Signal Compression

Nahidah Abdulhussein Kadim[1], Hend A. Elsayed[2], Shawkat K. Guirguis[3], and Ahmed S. Hameed[4]
1, 3 and 4 Department of Information Technology, Institute of Graduate Studies and Research, Alexandria University, Egypt
[2]Communication and Computer Engineering department, Faculty of Engineering, Delta University for Science and Technology, Egypt
[1]nnahida823@gmail.com; [2]hend.alielsayed@yahoo.coml; [3]shawkat_g@yahoo.com; [4]ahmed1418sami2012@gmail.com

Abstract

Compression is the art of representing information in a compressed form and not in its original or uncompressed form. In other words, using data compression. Image compression is a critical task in image processing, the use of discrete shearlet and improved image compression and quality. With the event within the field of networking and within the process of sending and receiving files, we would have liked effective techniques for compression because the raw images required large amounts of disc space to effect during transportation and storage operations.

In this paper, we have proposed a system for lossless picture compression using Discrete Shearlet Transform (DST), Discrete Wavelet Transform (DWT), and Discrete Cosine Transform (DCT)**.** We use lossless compression to take care of the first image during that process, but there's a serious problem which is frequently the low compression ratios.

The main objective of image compression is to reduce the frequency of image data, which helps to increase storage capacity and provide effective transport capacity. Image compression aids for decreasing the dimensions in bytes of a digital image without degrading the standard of that picture. There are various techniques available for compressing in this paper, we use the arithmetic coding, Huffman coding. This is to increase the compression percentage and indicate the effect on increasing the compression percentage. Also, three types of wavelet transformation were used, which are a separate shearlet transformation, separate wavelet transformation, and a separate cosine transformation.

The work of each of these three types was explained, and the effect of each type on the work of the proposed system was clarified. We also compared and demonstrated the differences between each type.

The results indicated that a separate shearlet conversion is one of the best types used with image lossless compression, especially when used with (Arithmetic coding).

Keywords: Discrete Shearlet Transform (DST), Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), Arithmetic Encoding, Huffman Encoding, Lossless, finger print, Lossless Compression.

الملخص

الضغط هو فن تمثيل المعلومات في نموذج مضغوط وليس في شكله الأصلي أو غير المضغوط. بمعنى آخر ، باستخدام ضغط البيانات . يعد ضغط الصور مهمة حاسمة في معالجة الصور ، واستخدام التحويل discrete shearlet وتحسن ضغط الصورة وجودتها. مع التطور في مجال الربط الشبكي في عملية إرسال واستقبال الملفات اقتضت الحاجة لتوفير تقنيات فعالة لضغط الصور حيث ان الصور الخام تتطلب كميات كبيرة من مساحة القرص الصلب للتأثير أثناء عمليات النقل والتخزين.

في هذه الورقة اقترحنا طريقة فعالة لضغط الصور بدون فقد (Lossless Image Compression) باستخدام تحويل منفصلة shearlet وتحويل المويجات المنفصلة وتحويل جيب التمام المنفصل . نستخدم الضغط بدون فقد للحفاظ على الخصائص الأصلية للصورة اثناء هذه العملية، لكن هناك مشكلة رئيسية وهي غالبا ما تكون نسب ضغط منخفضة.

ان الهدف الرئيسي من ضغط الصور هو تقليل التكرار من بيانات الصورة والتي تساعد في زيادة قدرة تخزين وتوفير قدرة نقل فعالة. يساعد ضغط الصورة على تقليل الأبعاد بالبايت للصورة الرقمية دون تقليل مقاييس تلك الصورة. هناك العديد من التقنيات المتاحة للضغط في هذه الورقة نستخدم حساب الترميز(Arithmetic coding) و ترميز هوفمان (Huffman coding).وذلك لزيادة نسبة الضغط وبيان تأثير على زيادة نسبة الضغط . أيضا تم أستخدام ثلاثة أنواع من مويجات التحويل وهي تحويل منفصلة shearlet وتحويل المويجات المنفصلة وتحويل جيب التمام المنفصل وتم شرح عمل كل نوع من هذه الانواع الثلاث وتوضيح تاثير كل نوع على عمل النظام المقترح كذلك قمنا بالمقارنة وأظهار الاختلافات بين كل نوع .

واوضحت النتائج ان تحويل منفصلة shearlet من افضل الانواع المستخدمة مع عملية ضغط الصور بدون فقد lossless (compression) خاصة عند استخدامها مع (Arithmetic coding).

الكلمات الرئيسية: تحويل Shearlet المنفصل (DST) ، تحويل المويجات المنفصلة (DWT) ، تحويل جيب التمام المنفصل (DCT) ، الترميز الحسابي ، ترميز هوفمان ، ضياع ، بصمات الأصابع ، الضغط بدون خساره.

I. Introduction

Compression is the art of representing the knowledge during a compact form instead of its original or uncompressed form. In other words, using the info compression, the dimensions of a specific file are often reduced. This is often very useful when processing, storing or transferring an enormous file, which needs many resources (Abood et al., 2016).

In this compression technique, no data is lost. The precise replica of the first file is often retrieved by decrypting the encrypted file. Text compression is usually of lossless type. During this sort of compression generally, the encrypted file is employed for storing or transmitting the file (Gupta and Rohit, 2016).

Lossless compression is used when it is important that the reconstructed, and original signals should be exactly identical, such as software or source code compression. The compression ratios in lossless compression schemes are not very impressive. Lossy compression is used when the reconstructed signal doesn't necessarily need to be the same as the input signal, but "close enough" to be useful. Most of video, audio and image compression techniques fall into this category, wherein high compression ratios can be accepted (Chengalvala et al., 2003).

The biometric recognition system today was very common and being a demanding system in many areas whose needed very high security on its own. By using biometric, the system was claimed to have many advantages such as special, robust and high privilege on its own for personal identification because it was believed that the biometric of each person cannot be shared, stolen and lost (Ahmad et al., 2017).

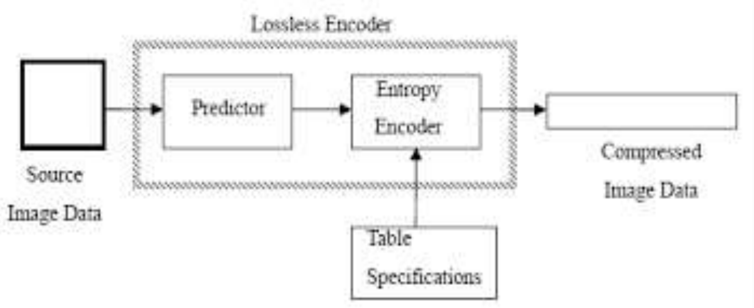

Fig. 1 Lossless compression

The proposed algorithm for the compression and decompression of the biometric signal composed four compressing procedures and four decompression procedures. For the compression, the first procedure is the transformation of the biometric signal using the discrete shearlet transform and compare the results using the discrete wavelet Transform, and discrete cosine transform, then preprocessing the output from the transformation procedure, the third procedure is to apply the lossless coding algorithm and then in the final procedure apply the lossless coding algorithm that is arithmetic coding algorithm and compare the results with the Huffman coding. The data block coming from the last compression procedure is transmitted to the server or a base station from e-health devices. The first decompression procedure applies the inverse lossless coding algorithm to the compressed data. In the final procedure, the biometric signal is reconstructed using the inverse transform.

Arithmetic coding is the code that represents a message through an interval of real numbers between 0 and 1. The longer the message becomes, the more the interval is needed to represent it. As the interval becomes smaller, the number of bits needed to specify it grows. Successive symbols of the message decrease the size of the interval according to the symbol probabilities generated by this model (Langdon et al., 2016). Huffman coding is an entropy encoding algorithm used for lossless data compression the representation for each symbol, resulting in a prefix code (sometimes called "prefix-free codes", that is, the bit string representing some particular symbol is never a prefix of the bit string representing any other symbol) that expresses the most common source symbols using shorter strings of bits than are used for less common (Venkatasekhar and Aruna, 2012)

2. Related Work

According to Kannan et al. (2010), Discrete Wavelet Transform plays a vital role in image fusion since it minimizes structural distortions among the various other transforms. Lack of shift invariance, poor directional selectivity and the absence of phase information are the drawbacks of Discrete Wavelet Transform.

Hasan et al. (2012) modify a spatial domain lossless image data compression method that uses simple arithmetic operations in order to reduce the coding redundancy of a digital image. After a careful exploration of the focused lossless image compression method and finding out its failure case, researchers took its existing improvements into consideration and revealed the limitations of such improvements.

Kaur Malwinder et al. (2015) survey literature on lossless image compression, introducing the basic concepts of image compression and providing an overview of various existing coding standards lossless image compression techniques define the lossless compression as being that compression which allows the original data to be perfectly reconstructed from the compressed data. Lossless compression programs do two things in sequence: the first step generates a statistical model for the input data, and the second step uses this model to map input data to bit sequences in such a way that probable.

Lim et al. (2015) developed the discrete shearlet transform (DST) which provides efficient multiscale directional representation and showed that the implementation of the transform was built in the discrete framework based on a multiresolution analysis (MRA).

According to Abo-Zahhad et al. (2015) the Huffman code is designed by merging the lowest probable symbols and this process is repeated until only two probabilities of two compound symbols are left. Thus, a code tree is generated and Huffman codes are obtained from labeling the code tree. The minimal length binary code for a two-symbol source, of course, is the symbols 0 and 1. The Huffman codes for the symbols are obtained by reading the branch digits sequentially from the root node to the respective terminal node or leaf. Huffman coding is the most popular technique for removing coding redundancy.

According to Sheltami et al. (2016), in image compression, the two-dimensional discrete cosine transform 2-Dimension DCT is very popular for its well-known energy compaction properties the 2-Dimension-DCT is obtained applying two separable one- dimension -DCT transforms along with the vertical and horizontal directions, respectively.

For this reason, it is very efficient at compressing images in which horizontal or vertical edges are dominating.

In this study, we assess the performance of the DST in image denoising and approximation applications. In image approximations, our approximation scheme using the DST outperforms the discrete wavelet transform (DWT), while the computational cost of our scheme is comparable to the DWT. Also, in image compression, the DST compares favorably with other existing transforms in the literature.

3. Theoretical Background

3.1Transform Compression Techniques'

Transform-based coding provides significant technical advantages over conventional transcoding techniques transform-based coding may provide lossless compression. Application order on data compression is increasing rapidly like modern technologies are growing high. High storage capacity is required for uncompressed images. Many images take the common characteristics as their neighboring pixels are highly correlated with redundant information. (Andrushia, et al., 2018). Image transformation phase received the resizable gray scale images and produced transformed images. This phase used the three types DST, DWT, and DCT.

3.1.1 Discrete Shearlet Transform (DST)

Signal and image compression have motivated intensive research, the low frequency information of signal has turned to be robust against many distortions like noise corruption. Therefore, the Shearlet coefficients in coarse scales are much preferable as they are robust against different type of distortions and transformations while maintaining high discrimination for perceptual different images. Moreover, the high ordered features are revealed by multi-directional decompositions of Shearlet. To demonstrate the property of coefficients of higher scales in Shearlet domain, the normalized sum of sub-band coefficient amplitudes is adopted for evaluation 1. (Yuan et al., 2016)

$$\boldsymbol{Pf(a,s)} = \frac{\Sigma\tau/sH\phi f(a,s,\tau/)}{Max\Sigma\tau/sH\phi f(a,s,\tau/)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(1)}$$

Where SH f a s t φ are the Shearlet coefficients with ast are the scale, direction and time parameter respectively where the (ψ) , SH f a s t φ are the Shearlet coefficients with , ast are the scale, direction and time parameter respectively, **ϕ**asτ, is called Shearlet coefficient.

3.1.2 Discrete Wavelet Transform (DWT)

The Discrete Wavelet Transform (DWT) of image processing system that provides a multi-scale representation of a given signal or picture. Standard DWT is helpless to shift variance problem and only has horizontal and vertical direction selectivity. In equation 2 and 3, suppose s represents a particular signal, n represents the sampling point, h and g represents a high-pass filter and low-pass filter, respectively, H and L represent the coefficients of high-pass and low-pass subbed. The picture signals provide a no redundant picture representation, who provide better spatial and spectral localization of picture formation, compared with other multi-scale representations like the Gaussian and Laplacian pyramid. (Kumar et al., 2016).

$$Y\ low\ [k] = \sum_{n} \chi[n].g\ [2k-n] \text{ Low pass filter output………. } (2)$$

$$Yhigh\ [k] = \sum \chi[n].h\ [2k-n] \text{ High pass filter output……… } (3)$$

Where, g (low-pass) and h (high-pass). Each resulting channel then is decimated by suppression of one sample out of two.

Y (k), can be obtained by the forward discrete transform and its inverse transform give the original signal sequence.

3.1.3 Discrete Cosine Transform (DCT)

DCT also features a vital property (energy concentration characteristics) most of the energy of natural signals (sound and image) is concentrated within the low-frequency part after DCT, so DCT is widely utilized in (sound and image) data compression DCT compression may compress the image in n x n metric formation. The DCT transforms the image into the pixels. The pixel of the image is transformed into**.** (Kumaret al., 2014)

$$Y(k) = \sum_{n=0}^{N-1} 2X(n)COS\left[\frac{\pi k(2n+1)}{2N}\right] \text{…………… } (4)$$

Where n, is spatial variable k, is transformed domain variable Y(k), can be obtained by the forward discrete transform and its inverse transform Gives the decomposed coefficient of the original signal and it gives more weight to low-pass coefficients to high-pass coefficients.

3.2 Lossless Compression Techniques

Lossless image compression techniques based on a predictive approach process image pixels in some fixed and predetermined order, modeling the intensity of each pixel as dependent on the intensity values at a fixed and predetermined neighborhood set of previously visited pixels. Hence, such techniques do not adapt well to the nonstationary nature of image data (Ansari et al., 2015).

3.2.1 Arithmetic Coding

Argue that Arithmetic coding yields better compression because it encodes a message as a whole new symbol instead of separable symbols .Most of the computations in arithmetic coding use floating-point arithmetic. However, most hardware can only support finite precision. While a new symbol is coded, the precision required to present the range grows. Context-Based Adaptive Binary Arithmetic Coding (CABAC) as a normative part of the new ITU-T/ISO/IEC standard. By combining an adaptive binary arithmetic coding technique with context modeling, a high degree of adaptation and redundancy reduction is achieved. The CABAC framework also includes a low-complexity method for binary arithmetic coding and probability estimation that is well suited for efficient hardware and software implementations (Hasan, et al., 2012).

3.2.2 Huffman Coding

The Huffman encoding (which is a Lossless compression techniques) starts with calculating the probability of each symbol in the image. The symbols probabilities are arranged in a descending order forming leaf nodes of a tree. When the symbols are coded individually, the Huffman code is designed by merging the lowest probable symbols and this process is repeated until only two probabilities of two compound symbols are left. Thus, a code tree is generated and Huffman codes are obtained from labelling of the code tree.

The minimal length binary code for a two-symbol source, of course, is the symbols 0 and 1. The Huffman codes for the symbols are obtained by reading the branch digits sequentially from the root node to the respective terminal node or leaf. Huffman coding is the most popular technique for removing coding redundancy (Abo-Zahhad et al., 2015)

4. Proposed Method

4.1 System Architecture

Image compression is an application of data compression that encodes the primary image with few bits. The target of compression is to reduce the redundancy of the image and to store or transmit data in an efficient form also minimizing the size in bytes of a graphics file without degrading the quality of the image to an unacceptable level. The reduction in file size allows more images to be stored during a given amount of disk or memory space. It also reduces the time required for images to be sent over the online or downloaded from sites. The diagram within the following figure (figure 2) shows the steps of the proposed method in sequence.

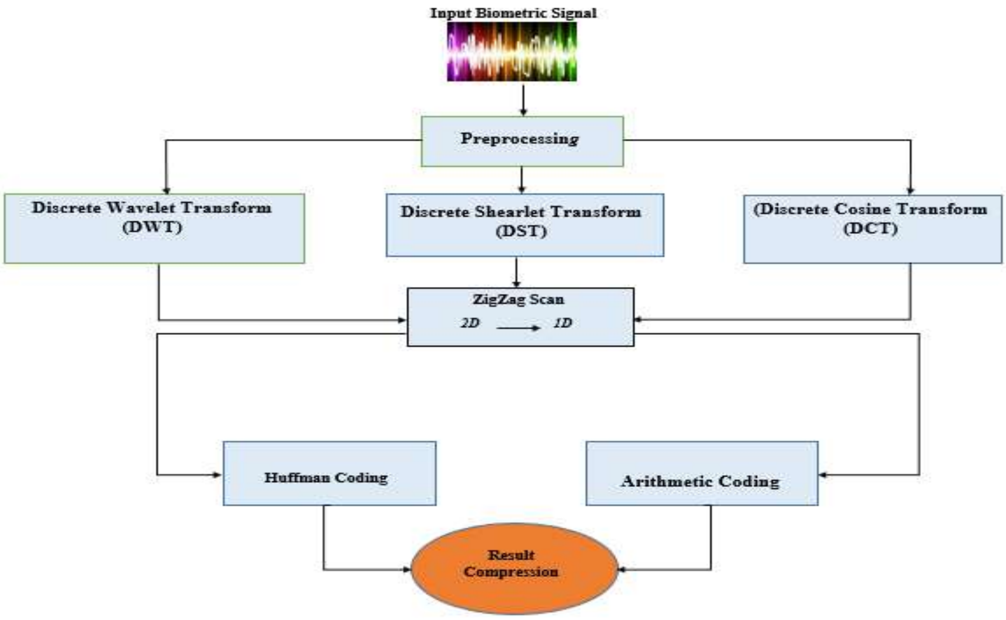

Fig. 2 Architecture of the proposed diagram

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4.1.1 Image Preprocessing

Preprocessing phase takes images as input, so that the proposed approach resize the image in accordance with the measured rate of different sizes to (16× 16) And then converted from (RGB) to (gray scale). Resize image reduces in both horizontal and vertical direction using equation 5.

fd (m, n) = f (2m,2n) ……………………..(5)

Where f (x, y) represents the original continuous image, fd (m, n) the sampled image (Blelloch et al., 2013)

While gray scale ways to convert a full-color image to grayscale, equation 3.2, gray scale algorithms utilizes the same basic three-step process:

1. Get the red, green, and blue values of a pixel
2. Use a fancy math to turn those numbers into a single gray value
3. Replace the original red, green, and blue values with the new gray value.

When describing grayscale algorithms, I'm going to focus on step 2 – using math to turn color values into a grayscale value. So, when you see a formula like this:

Gray = (Red + Green + Blue) / 3…………….(6)

Recognize that the actual code to implement such an algorithm looks like (Blelloch et al., 2013).

```
Preprocessing Algorithm RGB to Gray (image_matrix)
For Each Pixel in Image_matrix {
Red = Pixel. Red Green = Pixel. Green Blue = Pixel.Blue
Gray = (Red + Green + Blue) / 3
Pixel. Red = Gray
Pixel. Green = Gray
Pixel.Blue = Gray
}
Return image gray_matrix
```

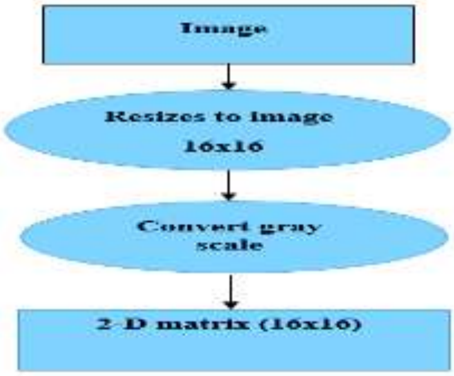

Fig. 3 Image pre processing

4.1.2 Image Transformation

(a) The transform of a function may give additional/ hidden information about the original function, which may not be available/obvious otherwise.

(b) The transform of an equation may be easier to solve than the original equation.

(c) The transform of a function/sequence may require less storage, hence provides data compression/reduction

(d) An operation may be easier to apply on the transformed function, rather than the original function

The term 'image transform' usually refers to a class of unitary matrices used for representing images. An image can be expanded in terms of a discrete set of basis arrays called 'basis images'. These basis images can be generated by unitary matrices.

There are three various methods of transformations being used for data compression named as follows, Shearlet transform DWT, and DCT.

4.1.3 Zigzag Scan

The zig-zag technique is based on scanning the image block by moving from the low-frequency component to the high-frequency component. After completion of the scan ordering, and according to the standard addressing of the matrix. In the Third step convert the matrix from Two-Dimension-to One-Dimension through the zigzag scan. Ordering converting a Two- Dimension-to One-Dimension arrays, in order this the frequency (horizontal + vertical) increasing during this order and therefore the coefficient change decreases during this order (Blelloch et al., 2013).

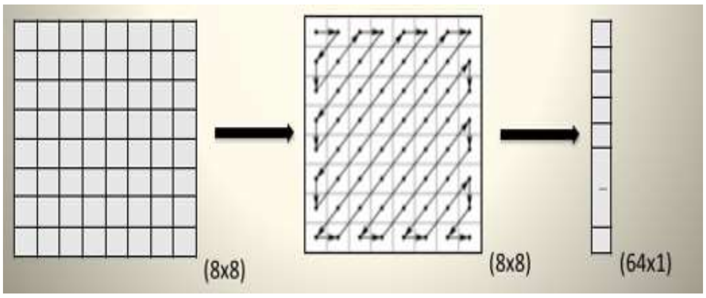

Fig. 4 Zigzag scan (Blelloch et al., 2013).

5. Experimental Results and Discussion

5.1 Dataset and its Characteristics

CASIA Fingerprint Image Database Version 5.0 (or CASIA-FingerprintV5) contains 20,000 fingerprint images of 500 subjects was utilized as a source of pictures. The fingerprint images of CASIA-FingerprintV5 were captured using URU4000 fingerprint sensor in one session. The volunteers of CASIA-FingerprintV5 counting graduate students, workers, waiters, etc. Each volunteer contributed with 40 fingerprint images of his eight fingers (left and right thumb/second/third/fourth finger), i.e. 5 images per finger. The volunteers were asked to rotate their fingers at various levels of pressure to generate significant intra-class variations. All fingerprint images are 8 bit gray-level BMP files and the image resolution is 328*356.

In the next step twenty different pictures were inserted in sequentially (grayscale) size (16 × 16) to 2 kinds of wavelet transforms as Discrete Wavelet Transform (DWT) or Discrete Cosine Transform (DCT).

Fig. 5 Sample of fingerprint image

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Table 1: Shearlet Transform Discrete Wavelet Transform and Discrete Cosine Transform with Arithmetic Coding.

SR.NO	Image	DST- zigzag Arithmetic Encoding			DWT - zigzag Arithmetic Encoding			DCT - zigzag - Arithmetic Encoding		
		Run Time	Bit Rate	C. Ratio	Run Time	Bit Rate	C. Ratio	Run Time	Bit Rate	C. Ratio
1	Fingerprint	0.194509	3.631696	2.202827	0.018743	4.785156	1.671837	0.115566	6.539063	1.223417
2	Fingerprint	0.163867	3.411830	2.344782	0.035918	4.843750	1.651613	0.020351	5.664063	1.412414
3	Fingerprint	0.157078	3.518415	2.273751	0.018127	4.472656	1.788646	0.035178	6.066406	1.318738
4	Fingerprint	0.227459	3.518415	2.273751	0.048039	4.785156	1.671837	0.159072	6.535156	1.224148
5	Fingerprint	0.322020	3.311384	2.415908	0.018344	4.722656	1.693962	0.046056	5.660156	1.413389
6	Fingerprint	0.260569	3.518415	2.273751	0.046713	4.609375	1.735593	0.051085	6.062500	1.319588
7	Fingerprint	0.295391	3.311384	2.415908	0.058703	0.058703	1.643660	0.068600	5.664063	1.412414
8	Fingerprint	0.544636	3.518415	2.273751	0.046078	4.492188	1.780870	0.065691	6.062500	1.319588
9	Fingerprint	0.273426	3.311384	2.415908	0.031357	4.722656	1.693962	0.124694	5.660156	1.413389
10	Fingerprint	0.265748	3.518415	2.273751	0.138845	4.558594	1.754927	0.113106	6.066406	1.318738
Average	Fingerprint	0.270403	3.4569753	2.3164088	0.0460867	4.205089	1.7086907	0.0799399	5.9980469	1.3375828

Table1 shows the results for the process lossless image compression of the ten images using the discrete shearlet transform, discrete wavelet transform, and discrete cosine transform, with arithmetic coding and the impact of each type on the image lossless compression. We find that DST Zigzag & Arithmetic the best thing, In terms of compression ratio, DWT Zigzag & Arithmetic, In terms of best thing compression time.

Table 2: Discrete Shearlet transform, Discrete Wavelet Transform, and Discrete cosine transform with Huffman coding

NO	Image	DST- zigzag - Huffman Encoding			DWT - zigzag - Huffman Encoding			DCT - zigzag - Huffman Encoding		
		Run Time	Bit Rate	C. Ratio	Run Time	Bit Rate	C. Ratio	Run Time	Bit Rate	C. Ratio
1	Fingerprint	2.575806	3.761719	2.126687	0.046402	5.105469	1.566947	0.107605	7.085938	1.128997
2	Fingerprint	2.632253	3.640067	2.197762	0.050083	4.792969	1.669112	0.000446	6.125000	1.306122
3	Fingerprint	2.759323	3.891183	2.055930	0.085046	5.558594	1.439213	1.034866	7.730469	0.110895
4	Fingerprint	3.034746	3.419643	2.339426	0.092782	4.867188	1.643660	0.141104	5.667969	1.411440
5	Fingerprint	2.642272	3.526786	2.268354	0.046832	4.500000	1.777778	0.125204	6.074219	1.317042
6	Fingerprint	2.615668	3.526786	2.268354	0.096439	4.824219	1.658300	0.329558	6.539063	1.223417
7	Fingerprint	3.036293	3.640067	2.197762	0.064108	5.519531	1.449398	0.116058	7.730469	1.034866
8	Fingerprint	2.941868	3.319196	2.410222	0.074387	4.738281	1.688376	0.175116	5.667969	1.411440
9	Fingerprint	3.105105	3.761719	2.126687	0.093833	5.171875	1.546828	0.136479	7.085938	1.128997
10	Fingerprint	2.983461	3.526786	2.268354	0.143938	4.609375	1.735593	0.196644	6.074219	1.317042
Average	Fingerprint	2.83268	3.601395	2.225954	0.079385	4.96875	1.617521	0.578125	6.578125	1.139026

Table2 shows the results for the process lossless image compression of the ten images using the discrete shearlet transform, discrete wavelet transform, and discrete cosine transform, with arithmetic coding and the impact of each type on the image lossless compression. We find that DST Zigzag & Huffman the best thing, In terms of compression ratio, DWT Zigzag & Huffman, In terms of best thing compression time.

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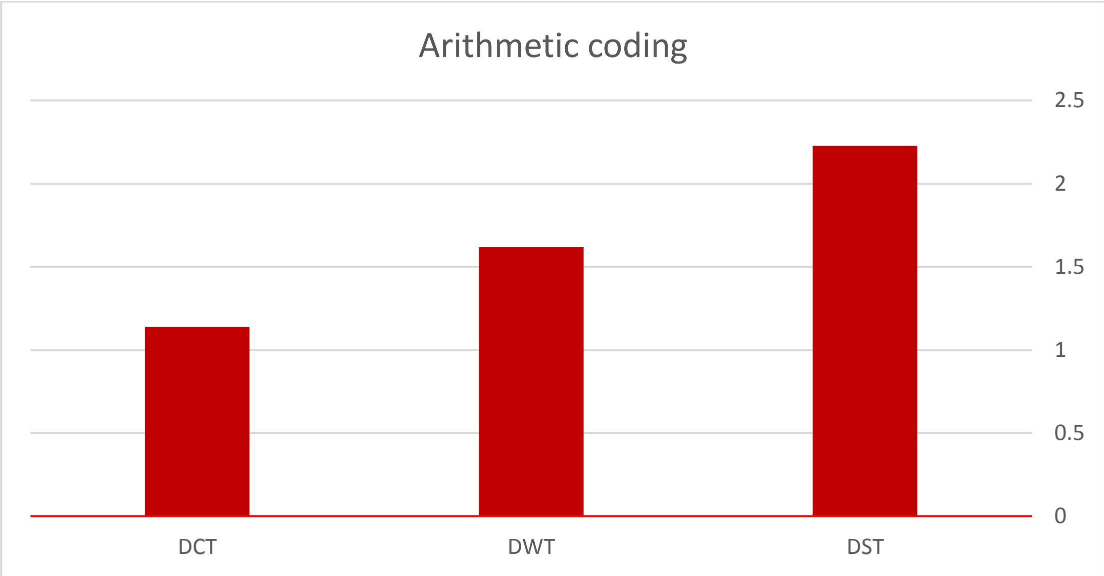

Fig.6 Comparison of DST, DWT and DCT based on 16X16 blocks with fingerprint image.

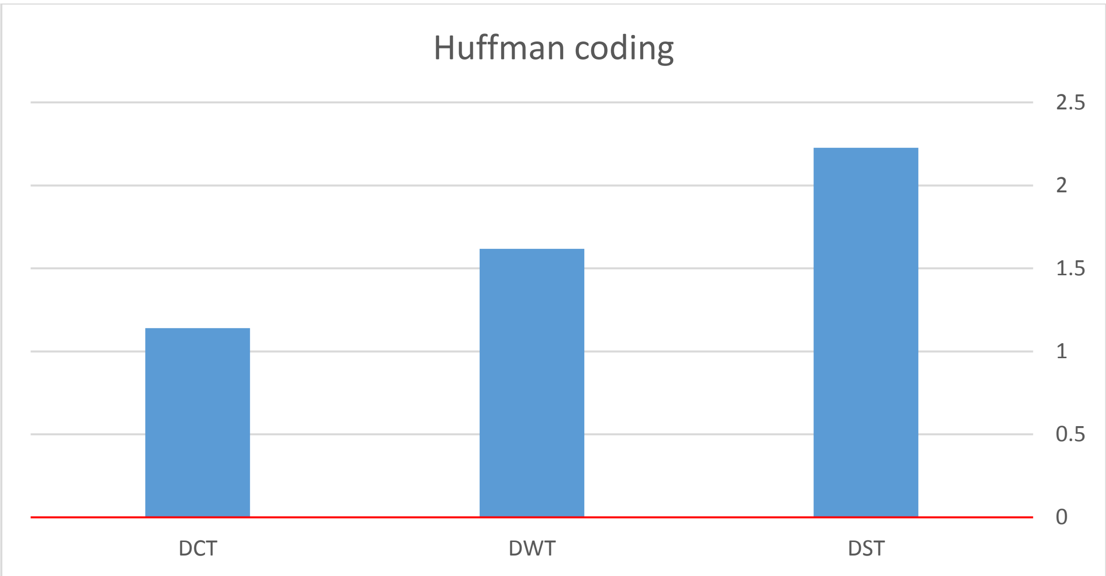

Fig.7 Comparison of DST, DWT and DCT based on 16X16 blocks with fingerprint image

6. Conclusion

This paper introduced a new approach that is built to work on image compression. Our approach used Arithmetic coding and Huffman coding with three types of transforms which are; Discrete Shearlet Tansform (DST), Discrete Wavelet Transform (DWT), and Discrete Cosine Transform (DCT.) Discrete Shearlet Transform (DST) compression ratio variable at a high level, either discrete wavelet transform (DWT) is less than the compression at a high level.

We conclude that arithmetic coding is better than Huffman coding in terms of compression ratio and time. We found that the best way to compression in this system is the discrete Shearlet transform (DST), and arithmetic coding where it gives the best compression ratio with less possible time.

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