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Fourier Transform Coding-based Techniques for Lossless Iris Image Compression

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Abstract

Today, the use of iris recognition is expanding globally as the most accurate and reliable biometric feature in terms of uniqueness and robustness. The motivation for the reduction or compression of the large databases of iris images becomes an urgent requirement. In general, image compression is the process to remove the insignificant or redundant information from the image details, that implicitly makes efficient use of redundancy embedded within the image itself. In addition, it may exploit human vision or perception limitations to reduce the imperceptible information.

This paper deals with reducing the size of image, namely reducing the number of bits required in representing the image. This was performed by exploiting the transforms-based coding techniques of lossless base compression system. In these techniques, the first part looked at the traditional Fourier transform coding technique while the second part aimed at enhancing the performance of the traditional transformation techniques. This was achieved once by overcoming the inherited problems of this technique that suffers from the complex nature base, then latter by incorporating the double base coding techniques of hierarchal scheme, as mixing of both discrete wavelet transform and zipper coding techniques.

The test results indicated that the proposed scheme produced high compression ratio with identically preserving the quality of the compressed (decoded) image.

Keywords: decoded image, zipper

تحويل فوريير (Fourier) تقنية قائمة على الترميز لضغط صورة القرنية بدون فقدان للبيانات

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الخلاصة

يعتبر التعرف على قرنية العين في الوقت الحالي هو السمة البيومترية الأكثر دقة وموثوقية من حيث التفرّد والقوة ، الذي يتوسع استخدامه عالمياً. تخفيض أو ضغط قواعد البيانات الكبيرة لصور قرنية اصبح مطلباً ملحاً. بشكل عام ، يعد ضغط الصور هو عملية إزالة المعلومات غير الضرورية أو الزائدة عن تفاصيل الصورة، والتي تعمل ضمناً على الاستخدام الفعال للتكرار المضمن داخل الصورة نفسها. بالإضافة إلى ذلك، قد تستغل الرؤية البشرية أو حدود الإدراك لتقليل المعلومات غير المفهومة.

يتناول هذا البحث تقليل حجم الصورة، أي تقليل عدد البتات المطلوبة في تمثيل الصورة، والتي يتم تنفيذها باستخدام تقنيات الترميز المعتمدة على تحويلات نظام الضغط بدون فقدان، حيث يستخدم في الجزء الأول تقنية التحويل التقليدية من فوريير (Fourier) ، والجزء الثاني يهدف إلى تحسين أداء تقنيات التحويل التقليدية، بواسطة التغلب على المشاكل الموروثة لهذه التقنية التي تعاني من طبيعتها المعقدة، ثم الجزء الأخير من خلال

دمج تقنية الترميز المزدوجة للمخطط الهرمي ، كما في الخلط بين كل من تقنيات تحويل الموجات المنفصلة وتشفير الـ (Zipper).
 اشارت نتائج الاختبار إلى أن المخطط المقترح يعطي نسبة ضغط عالية مع الحفاظ على جودة الصورة المضغوطة (فك الشفرة).

1. Introduction

Iris recognition system for identifying authentication and verification is one of the most precise and accepted biometrics that is gaining popularity in the world. The iris is the colored portion of the eye surrounding the pupil, contains unique patterns which are prominent under near-infrared illumination. These patterns remain stable from a very young age, barring trauma or disease, allowing accurate identification with a very high level of confidence [1].

The enrolment of an individual into a commercial iris system requires capturing one or more images from a video stream. Typically, the database for such system does not contain actual iris images, but rather it stores as a binary file that represents each enrolled iris (the template), which requires huge bytes per eye to be stored (i.e., 307,200 bytes for a 640×480 grayscale image) [1]. This implicitly needs to minimize the size of image through the utilization of data compression techniques.

Image compression plays an essential role for effective transmission and storage of images [2]. The image compression systems are based on exploiting the redundancy within the image itself, along with the utilization of the limitations of human vision or perception [3]. Generally, they fall into two categories: *lossless* and *lossy*, depending on the redundancy(s) type(s) exploited [2]. Description of various *lossless* and *lossy* techniques can be found in previous reports [3-8].

During the last few years, several image compression techniques were developed in biometric systems such as the iris recognition system. Different types of image compression standards, including *JPEG* and *JPEG-2000*, were utilized to generate the compact iris data [2]. But, sometimes the *lossless JPEG* is not suitable for high compression ratios; another limitation is the blocking artifact that can occur at high compression ratio in case that the *lossy*-based system is used [2]. However, the challenge and necessity of improving efficient performance of biometric the iris compression system grew, since this data is increasing day by day, which becomes an increasingly intensive and important research area to design and adopt modern techniques [3].

Actually, most of the work on biometric iris sample data investigated the effects of image compression on recognition system performance, which clearly showed the inverse relation between the compression performance and recognition accuracy; when the compression rate increases, the recognition accuracy decreases, and vice versa [9]. Also, some efforts compared between different variants of *lossless* and *lossy* standard techniques (*lossless: JPEG, JPEG-LS, PNG, GIF, JPEG2000, and JPEG XR*) [10] and various extended forms of Discrete Wavelet Transform (*DWT*) that imply the Set Partitioning Into Hierarchical Tree (*SPIHT*) and Embedded Zero-Tree wavelet (*EZW*) coding techniques [11], along with curvelet transform in combination with lifting Wavelet [2]. The Region Of Interest (*ROI*) was also adopted to achieve highly compressed image quality [12]. Lastly, the hybrid technique was utilized efficiently as a mix between Lempel-Ziv-Welch (*LZW*) and Huffman coding [13].

The researchers exploited the Fourier transform as a tool to compress images in the last century, by exploiting the frequency domain image efficiently; each pixel represents a particular frequency contained in the spatial domain image, while compression occurs by modifying these coefficients. Some efforts aimed to improving the performance of the traditional Fourier transform-based technique, either by utilizing different variable block sizes instead of the fixed one [14], or using various quantization schemes of adaptive- or optimized-based techniques, where all the techniques still suffer from the existence of the imaginary embedded between the coefficients. Today, zipper transform is effectively in use, that exploits the conjugate symmetry property of Fourier transformation base to overcome the drawback of the traditional technique [15].

In this paper, an efficient method for compression biometric iris grayscale image is introduced that integrates the multiresolution scheme of *DWT* base along with the zipper transformation base techniques. The rest of the paper is organized as follows: sections 2, 3 and 4 contain comprehensive clarification of the traditional Fourier transform, zipper transform and the proposed system; the results for the proposed system are provided in section 5, and the conclusion in section 6.

2. Iris Image Compression Using Traditional Discrete Fourier Transform Technique

Basically, the Discrete Fourier transform (*DFT*) acts in mapping or transforming the input into coefficients using the linear combination of weighted basis function corresponding to the sine and cosine bases [16,17]. The implementation of the traditional discrete Fourier transform compression system is explained in the following steps [14-17].

Step 1: Load the input uncompressed iris gray image I of *BMP* format of size $N \times N$.

Step 2 Partition image I into non-overlapped blocks (regions) to exploit the local similarity. Namely, the image needs to be partitioned into several smaller, non-overlapping blocks, that are either of fixed size ($n \times n$) (i.e., $n < N$) or of variable sizes ($n \times q$) (i.e., $n < N$ & $q < N$). For the first of these, the fixed partitioning method is adopted in this paper because of its simplicity and popularity. However, this occurs at the expense of efficiency and comes with a greater storage cost, because the blocks are partitioned based on the size of the region, regardless of the content and whether that region or block is uniform or non-uniform [3].

Step 3: Apply forward discrete Fourier transform on each segmented block according to the equation below.

Where $I(i,j)$ is the input correlated image of i, j are the spatial coordinates and u, v are coordinates in the transform domain. $F(u,v)$ is the transform coefficient at position (u,v) , where $u, v, i, j = 0, \dots, n-1$, also the base of the natural logarithmic function e is about 2.71828; and j_{comp} is the imaginary coordinate for a complex number, equals $\sqrt{-1}$.

Step 4: Apply symbol encoding techniques to remove the coding redundancy embedded within the Fourier coefficient's of complex nature.

Step 5: Reconstruct or rebuild the compressed or decoded image which is identical to the original one I , from the encoded coefficients, the decoder, simply use the inverse Fourier transform using the following equation:

3. Iris Image Compression Using Zipper Transform Technique

The core of zipper transform is identical to the Fourier transform, where this transformation coding-based technique aimed to decorrelate the input efficiently by utilizing the conjugate symmetry property of Discrete Fourier Transformation (*DFT*).

The technique simply starts from the original uncompressed iris image I , then implementing the discussed traditional Fourier transform coding method (*DFT*), where the output of *DFT* is a set of complex numbers having a property known as the conjugate symmetry, based on exploiting the interlacing and the concatenating zipper transform. The interlacing zipping operation is abstracted from the way and two separate entities can be fastened and tightened with a zipping tool. In the case of interlacing-*ZT* which corresponds to the forward transformation, the imaginary parts of the complex numbers in the upper half of the symmetry are stripped off and interlaced with their corresponding real counterparts that are subsequently encoded using Huffman coding techniques. In the concatenating *ZT* (or simply *ZT*) on the other hand, the imaginary parts of the complex numbers in the upper half of the symmetry are stripped off and concatenated with their corresponding real counterparts that are corresponding to inverse transformation [15], followed by applying the *IDFT* to reconstruct the identical image I

4. Iris Image Compression Using Double Transformation Technique

In order to improve the performance of the zipper transform, which is an adaptive form of Fourier transform, the discrete wavelet transform (*DWT*) of Haar base of one multiresolution decomposition scheme was adopted. Due to less information being used compared to the original image (i.e., the use of a quarter part of the image instead of the whole image), the following steps were applied to compress iris image *losslessly*.

Step 1: Load the input uncompressed iris gray image I of *BMP* format of size $N \times N$.

Step 2: Perform a wavelet transform that decomposes I image into four quadrants of *approximation* and *detail* sub bands (I_{LL} , I_{LH} , I_{HL} and I_{HH} , respectively), each has the size of $N/2 \times N/2$, where each sub band (approximation and details) was compressed differently. In other words, the I_{LL} , I_{LH} , I_{HL} and I_{HH} sub band partitions indicate the approximation image (average image) and the images with horizontal edges, vertical edges and diagonal edges, respectively.

Step 3: Apply the Zipper Transform of lossless base on the approximation I_{LL} subband.

Step 4: Encode the details (I_{LH} , I_{HL} and I_{HH}) subband *losslessly* using the symbol encoder of probability base.

Step 5: To reconstruct the decoded or compressed identical iris image I , the decoder reconstruct the approximation subband using the inverse transforms of zipper then then Fourier based respectively, and detailed sub bands coded information, with the inverse *DWT*.

5. Experimental Results

In order to test the performance of the traditional Fourier coding based techniques and comparing it with that of the zipper-based methods and the proposed double transformation-based technique, four standard gray (256 gray levels or 8 bits/pixel) square (256×256) images of highly details were utilized as shown in Figure-1. Also, the compression ratio was adopted as criteria of lossless system base (see equation 3), which is the ratio of the original image size to the compressed size in bytes. Here, the original image size corresponds to the size of the image represented by its width and height, resembling the number of rows and columns, respectively. The compressed size involves the encoding of the compressed size that is composed of size in bytes of DFT coefficients of real and imaginary parts (equation 4). Lastly, the size of the saved bytes corresponds to the difference between the original image size and the compressed image size (equation 5).

$$\text{Comp.Ratio} = \frac{\text{Size of original image in bytes}}{\text{Size of compressed image in bytes}} \quad (3)$$

$$\text{Size of compressed image} = [\text{Size in bytes for real image} + \text{Size in bytes for imaginary image}] \quad (4)$$

$$\text{Size of Saved Bytes} = [\text{no.bytes for original image} - \text{no.bytes for compressed image}] \quad (5)$$

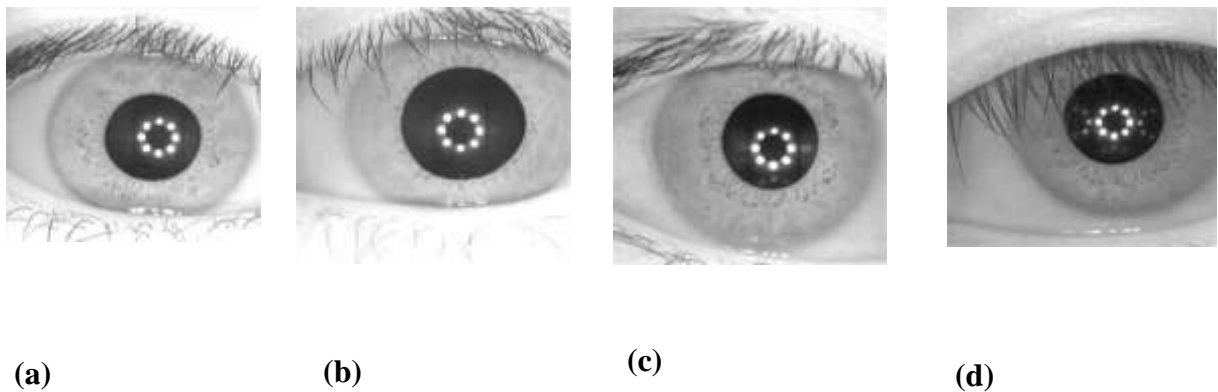


Figure 1-The four tested images of size 256×256 , grayscale images, (a) Iris1, (b) Iris2, (c) Iris2 and (d) Iris4.

The results shown in Table-1 illustrate the comparison between the traditional Fourier transform, zipper transform and the proposed techniques, along with the utilization of the compression ratio and the size in bytes between the original and compressed images by using block size of 4×4 .

Table -1 Comparison of the performance between traditional discrete Fourier transform, adaptive discrete Fourier transform of zipper base and double transformation of discrete wavelet transform using block size of 4x4 of tested images.

Tested Image & Size in Bytes	Traditional discrete Fourier transform			Adaptive discrete Fourier transform of zipper base			Double transformation of discrete wavelet transform		
	Comp. Ratio	Size in bytes of compressed information	Size of Saved Bytes	Comp. Ratio	Size in bytes of compressed information	Size of Saved Bytes	Comp. Ratio	Size in bytes of compressed information	Size of Saved Bytes
Iris1	4.6355	14138	51398	8.6642	7564	57972	13.8818	4721	60815
Iris2	4.2834	15300	50236	8.0078	8184	57352	13.8730	4724	60812
Iris3	4.5073	14540	50996	8.4237	7780	57756	13.1072	5000	60536
Iris4	4.2901	15276	50260	8.0215	8170	57366	14.0665	4659	60877

There is a number of issues that need to be highlighted according to the above results:

- 1- Obviously, the traditional Fourier compression system of the complex base provides lower compression ratio, since it would need greater range of values than the image in the spatial domain.
- 2- By utilizing zipper coding base, the higher compression ratio achieved, which was improved about twice in average as compared to the traditional Fourier coding for the tested images. This was due to the interlacing and the concatenating of complex coefficients.
- 3- It is clear that, by incorporating double transformation coding techniques, a higher compression ratio is attained due to the utilization of the decomposition base of approximation and detailed subbands.

Figure-2 demonstrates the performance of the traditional discrete Fourier transform of zipper base and double transformation base of the tested images using 4x4 block size.

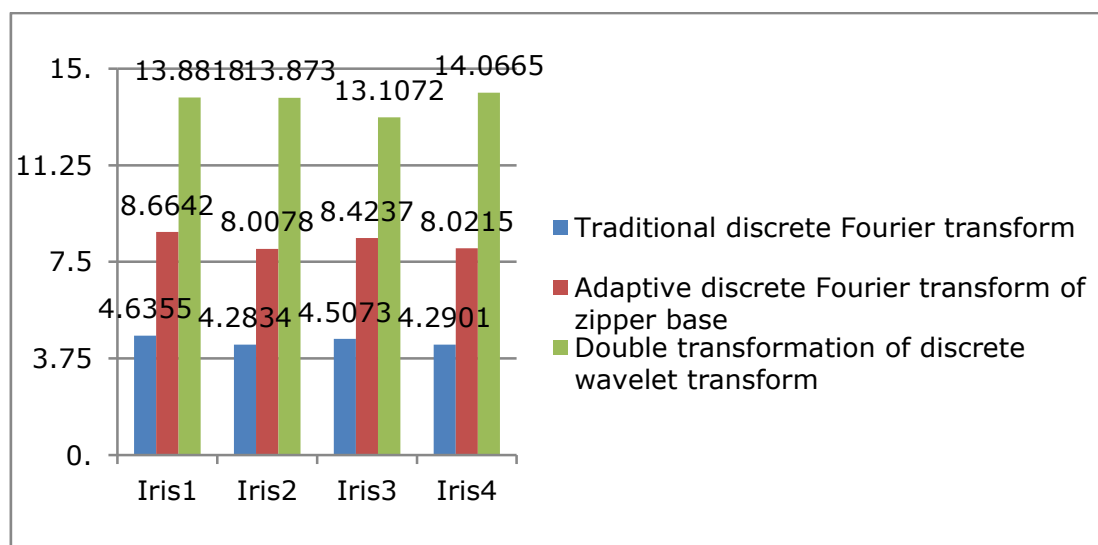


Figure 2-The performance of the traditional discrete Fourier transform, of zipper base and double transformation base of Iris1, Iris2, Iris3 and Iris4 image using 4x4 block size.

6. Conclusions

- 1) The traditional Fourier coding technique is characterized by simplicity, but on the expense of efficiency in terms of low compression ratio.
- 2) The adaptive discrete Fourier transform of zipper base efficiently improves the results, due to the exploitation of the interlacing and the concatenating in encoding and decoding processes, respectively.
- 3) The incorporation with the one-layered wavelet transforms of Haar base enhances the results, as achieved by the utilization of quarter part of the image as compared to the detailed subband.

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