# PROGRESSIVE FINGERPRINT IMAGES COMPRESSION USING EDGE DETECTION TECHNIQUE

**Awad Kh. Al-Asmari**
Electrical Eng. Dept., College of Engineering
King Saud University, Riyadh 11421, Saudi Arabia
E-mail: akasmari@ksu.edu.sa

**الملخص:**

*تم في هذه الورقة بناء خوارزم جديد للضغط المتتالي للبصمات الرقمية لأرسالها أو حفظها بأستخدام كاشف الحواف. قسمت الصور إلى مركبتين (أولية و ثانوية). حيث أن حواف الصورة وضعت في المركبة الأولى ، بينما المركبة الثانية تحتوي على الهيئة و البنية الأساسية للبصمة . في هذا البحث إستطعنا الحصول على شكل مبدئي للعينة (١) عند معدل ٠،٠٢٢٣ بته لعنصر الصورة و ٠،٠٢٤٥ بته لعنصر الصورة للعينة (٢). حصلنا على الصورة المسترجعة عند معدل ٠،١٨٠ بته لعنصر الصورة يعني بمعدل ضغط يصل إلى ٤٥ : ١ . هذا الخوارزم يعطي نتائج تضاهي مثيلاتها لخوارزميات أخري ، على سبيل المثال خوارزم المباحث الأمريكية الفيدرالية القياسي للبصمات.*

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**Awad Kh. Al-Asmari**
Electrical Eng. Dept., College of Engineering
King Saud University, Riyadh 11421, Saudi Arabia
E-mail: akasmari@ksu.edu.sa

## Abstract

*In this paper, a progressive fingerprint image compression (for storage or transmission) using edge detection scheme is adopted. The image is decomposed into two components. The first component is the primary component, which contains the edges, the other component is the secondary component, which contains the textures and the features. In this paper, a general grasp for the image is reconstructed in the first stage at a bit rate of 0.0223 bpp for Sample (1) and 0.0245 bpp for Sample (2) image. The quality of the reconstructed images is competitive to the 0.75 bpp target bit set by FBI standard. Also, the compression ratio and the image quality of this algorithm is competitive to other existing methods given in the literature [6]-[9]. The compression ratio for our algorithm is about 45:1 (0.180 bpp).*

**Key Words**: Progressive Image Transmission, Fingerprint Compression, Edge Detection, Vector Quantization.

## 1. INTRODUCTION

Fingerprints are vital forensic tools used around the world by the police departments to identify suspects and bodies. It is also one of the biometric currently been considered for identification and access control to facilities (systems and networks). With time, huge numbers of fingerprints images have been collected and stored in paper databases. These paper databases have proven not to be an efficient way to store fingerprints images especially with increasing demands for simple access and fastest transmission of these images between police departments. Fingerprints images can be digitized and stored in electronic memories. One problem to be faced when using digitization is how to obtain the finer details of the fingerprints? The image must be represented with huge number of bits, which will need a large memory and large transmission time or large bandwidth. To achieve higher compression ratios, regular structure of fingerprint images should be utilized by means of model based coding techniques [1]-[3].

Several different methods have been reported for fingerprint compression in the literature. They can be divided into two categories [4]: (a) – fingerprint data compression techniques, which are based on *extracting and compression essential data* in fingerprints like ridges and/or feature. These techniques are not able to reconstruct the compressed fingerprint images [2]-[3]. (b) – fingerprint image compression techniques based on *transforms suited* for these kind of images. Some other techniques belong to this category such as vector quantization is used [5]. These techniques of category (b) can not achieve higher compression ratio than that of category (a) because they did no utilize the regular structural properties of the fingerprints. There are many proposed algorithms in the literature which adapted category (b) such as the FBI standard for fingerprint compression [6].

The US Federal Bureau of Investigation (FBI) has developed a standard to compress digital fingerprint images so that the fingerprint images can be transmitted and stored efficiently with minimum loss to the vital details. This standard is referred to as Wavelet/Scalar Quantization compression (WSQ), which depends on a signal processing theory called the wavelet transform [6]. Several other algorithms which utilizing the wavelets concept have been reported in the literature [7]-[9]. The main goal of these algorithms are to obtain specialized wavelets which take advantage of the local space-frequency structures particular fingerprint images [9].

In this paper we proposed a progressive compression scheme for the fingerprint which enables us to achieve high compression and in the same time reconstruct the fingerprint from the compressed data. The algorithm combines the advantages of the above mentioned tow categories used for fingerprint compression. Edge detection technique enables us to progressively reconstruct the fingerprint image from ridge skeleton. In this approach, the compression is based on deriving the most important information about ridge and valley skeletons by using the Canny edge detection method. To reduce the numbers of detected edges to be compressed, a predefined mane plates will be correlated with the extracted edges, and then extract the macro edge in sixteen directions (i.e. in step of 11.25 degree). The aim of detecting macro edges is to reduce the number of gaps in the fingerprint edges, and therefore, to reduce the number of edges to be encoded. Itoh in [10] has adopted Laplacian method with thresholding for gray scale images. We find that his technique will not detect the edges for areas with small intensities variation in the image. Therefore, we proposed using Canny edge detection method for fingerprint images which have small variations at the ridges and the valleys. This technique will maintain the important features such as the end points and the bifurcation points which can be obtained from the ridge skeleton even at a very high compression ratio.

This paper is organized as follow. In section 2, the images compression using edge detection technique is presented. The progressive fingerprint images compression using edge detection method is discussed in section 3. In this section more detailed information for the proposed algorithm is presented. The simulation results are given in section 4. Conclusions and recommendations have been presented in section 5.

## 2. IMAGE COMPRESSION USING EDGE DETECTION

The coding model employed for edge detection coding schemes is based on the multi-component source model [11]. It decomposes the gray scale image into primary component, which contains the edge information, and secondary component, which represents the slow intensity variations. A lot of approaches put emphasis on the edge detection, representation and coding, which has a significant impact on the quality of the reconstructed image. Most of the edge detection schemes are thwarted by gaps in the data produced by local noise and readily follows by spurious boundaries, as well as the location errors of extracted edges, which will lead to edge discontinuity and incorrect intensity values [12].

In the literature there are many methods have been introduced for edge detection. In this paper, we adopted Canny method for edge detection, which it depends on zero crossing for detecting edges even at small intensities variation. Also, Canny method has been found to have the lowest MSE for the reconstructed image, when compared with other edge-detection methods such as Sobel, Roberts, and Prewitt [13]. The method can be seen as a smoothing filtering performed with a liner combination of exponential functions, followed by derivative operations. The size of the exponential filter is related to the width of gray level transition region, as well as to the noise level in the image. The edge detection methods proposed in [10]-[13] are suitable for regular gray scale images but not for fingerprints image. In this paper, we proposed a modified edge detection compression technique tuned for gray scale fingerprint images. In this technique, the fingerprint image is decomposed into primary component, which contains the edge information of the ridges (dark curves) and the valley in the fingerprint, and secondary component, which represents the original structural properties of the fingerprint image.

### 2.1. Extracting the unit edges

The edges will be detected by using Canny method. The scheme for unit edge detection is shown in Figure 1. Canny method is first applied to detect the edges in the fingerprint image. Then, a sub-block of 5x5 from the edge image will be correlated with a pre-selected eight nameplates. The aim of these nameplates is to replace the edges detected by Canny method with the corresponding nameplates. This will reduce the number of edges in controllable way and keeping the important information about the ridge skeleton. In our approach, the ridge skeleton is extracted from the ridges by applying. These nameplates are shown in Figure 2. The correlation method is implemented according to the following equation:

$$R_n(x,y) = \sum_j \sum_k B_{sb}(x+j, y+k) T_n(j,k) \qquad (1)$$

Where $n$ is an integer number equal to 0, 1, 2, …, 7, $(j,k)$ are an integer number depends on the size of the nameplate equal to 0, 1, …, 4, $B_{sb}$ is the sub-block taken from the image after thresholding, $T_n$ is one of eight nameplates, and $(x,y)$ are $L/5$ each, where $L$ is the fingerprint dimension.

If there exist $n$ such that $R_n(x,y)$ greater than or equal to a predefined threshold $(P_{th})$, a unit edge will be detected and replaced with the nameplates that satisfy the criteria given below:

$$R_n(x, y) \geq P_{th} \tag{2}$$

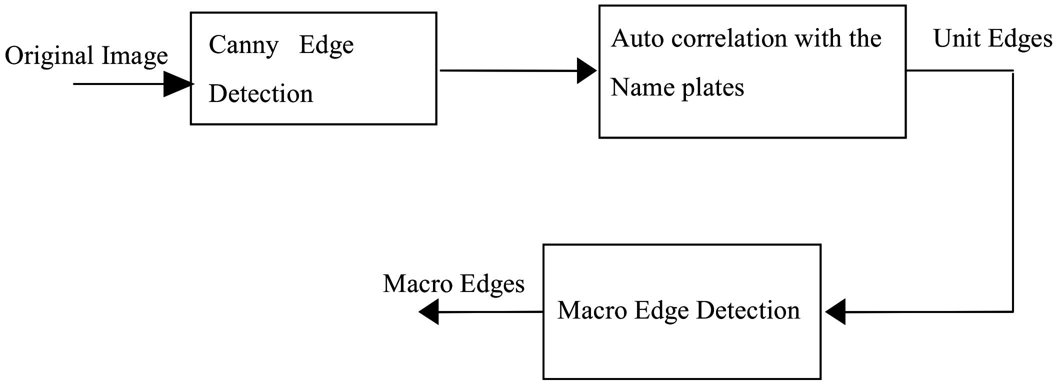



Figure 1. The unit edge detection process.

## 2.2. Extracting Macro edge

After extracting the unit edges as discussed in the previous section, we will detect the macro edge (in sixteen directions only) along the circle around the designated unit edge. These directions will be 11.25 degrees each as presented in [10]. The aim of detecting macro edges is to reduce the number of gaps (edges connection), to give smoothing for the interpolation process, and to reduce the number of edges in the unit edge fingerprint image to be compressed. Also, to keep these edges which are necessary to reconstruct the ridge skeleton with acceptable visual quality.

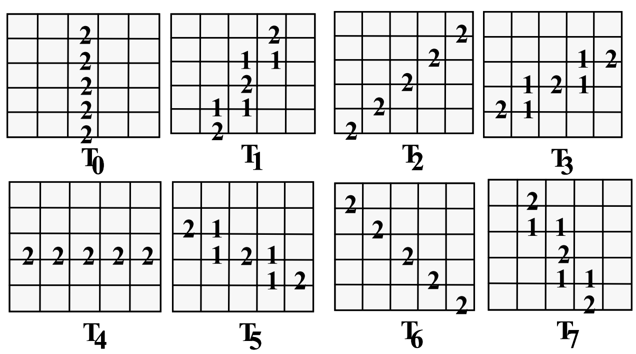


Figure 2. Eight directional small segment patterns.

# 3. PROGRESSIVE FINGERPRINT COMPRESSION USING EDGE DETECTION

A progressive image transmission is adopted to overcome the edge discontinuity and incorrect intensity values problems of edge detection and to involve an approximate reconstruction of the image whose fidelity is built up gradually until either the viewer decides to abort the transmission or perfect reconstruction is achieved.

The applications benefiting from this algorithm are in transmitting the images over low bandwidth channels such as wireless channels and telephone lines. Examples for such applications are access to remote fingerprint image databases, electronic shopping, and security systems. The last couple of years have seen an explosive growth of business-to-customer activities over the Internet. The total dollar value of these web-based transactions is over several billion US dollars [14]. The present transaction over the web is not capable of assuring that the rightful owner of the credit card is the one who initiate the transaction. Furthermore, the present practice is not capable of linking the transaction to the rightful owner to the credit card. Very soon, credit card owners and credit card issuers will demand more reliable and secure authentication techniques that link the owner of the credit card and the transaction with the help of fingerprint [14]. For these applications, it is important for the viewer to recognize the content as early as possible in the transmission.

In this section, the encoding of primary and secondary components will be presented. For the primary component, a combination of Huffman code and vector quantization (VQ) is designed for the nameplates. This encoding process reduced the required bit to transmit the compressed macro edges.

### 3.1. Codebook design for the primary component

Two neighbor nameplates are assumed to be the codeword of the design codebook. The size of the codeword will be a sub-block of size 5x10 from any two combinations of the nine nameplates. The size of the codebook will be $9^2$, which is self generation from the original nameplates. In this research paper, we tested ten different fingerprints images to design an optimal codebook. A sub-block of 5x10 from the test fingerprint image is taken and compared with the eighty one possible combination of the codebook. One of the codebook will give an exact representation of the input sub-block. The index of this entry codeword will be sent at a rate of 7 bits (0.14 bit per pixel). To obtain a high compression ratio, the Huffman coding concept for the codebook indexes (to know how many times each combination of the nameplate will occur) is implemented. The ten test fingerprint images are used to design the Huffman code.

From the experimental results, we find that most of the nameplates combinations have zeros or ones occurrence. These nameplates will be discarded to reduce the codebook entries. There are only 16 codeword, which will reduce the required bit rate for the first stage encoded image to be (4/50) bit per pixel (bpp). Designing a Huffman code for the 16 code vectors of the codebook can further reduce this rate. The first three layers primary components, which contain the high frequency, have been transmitted to give a general grasp of the image for a person who wants to browse through a remote database of fingerprint images. The overall progressive fingerprint images compression technique proposed in this paper is shown in Figure 3.

### 3.2. Codebook design for the secondary component

The smooth component is the difference between the original image and the reconstructed primary component, which consists of summation of three stages of the reconstructed fingerprint images. This component will be decimated using minimum average entropy filter [15]. Then, the smooth component will be encoded using VQ. The codebook size is 256 vectors (codewords) each of length 16 pixels. 40960 vectors, which represent the ten decimated fingerprint images, are used to design the global codebook. The distortion measure (ε) is the mean square error (MSE). The ratio of the MSE between the new codebook and the previous codebook will be calculated according to the following equation:

$$R = \frac{E^k - E^{k+1}}{E^{k+1}} \tag{3}$$

Where $R$ is the relative MSE, $E^k$ is the MSE of the previous codebook, and $E^{k+1}$ is the MSE of the new codebook. If the ratio $R \geq \varepsilon$, equation 3 will be repeated again for new process until $R$ became less than the target MSE Ratio (ε). In this paper ε is selected to be $10^{-4}$. At the receiver, the two components (primary and smooth) have been added to form the reconstructed image.

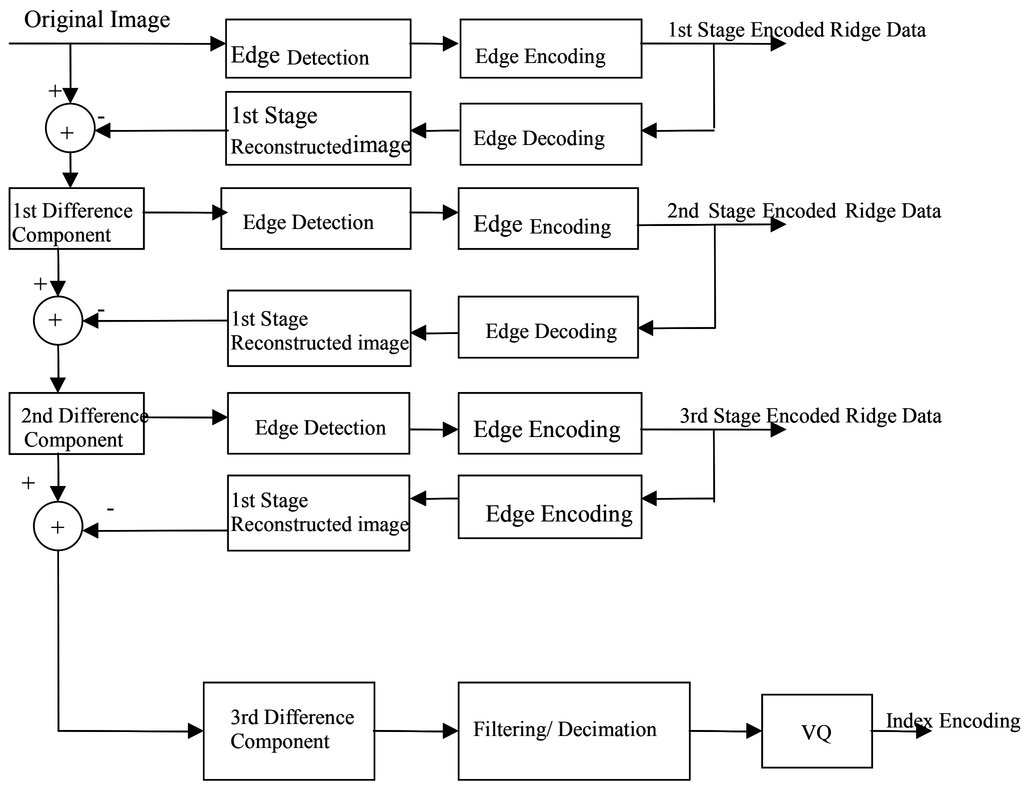



Figure 3. The overall proposed edge-detection encoding scheme for progressive image transmission.

## 4. SIMULATION RESULTS

The experimental results in this paper are given for two samples from the ten tested fingerprint images. Figure 4 shows the original images of sample (1) and sample (2). The Canny edge detection method is implemented for these two test samples as shown in Figure 5 (a) and (b). As can be seen from this figure, that it approximate the binary representation of the original images. Figure 5 (c) and (d) reduce the edges by using the nameplates replacement proposed in this algorithm so we can have a great compression ratio. To further reduce the number of edges and keep those which have the important feature of the fingerprint, we apply the macro edge detection concept as shown in Figure 5 (e) and (f). These images (figure 5 (e) and (f)) are used to compress the fingerprint images to be stored or transmitted.

Figure 6 shows the three stages reconstructed fingerprints at different peak signal to noise ration (PSNR) in dB, and at different bit rate (bpp) as shown in Table 1. The reconstructed images in this figure are used to be added to the secondary reconstructed component. The visual quality of the reconstructed primary component is improved gradually as of transmitting additional information at an increased bit rate. Figure 6 can be considered to be the ridge data of the fingerprint images. The accumulative interpolation process (at the receiver side) for these data gave us primary information about the ridge skeleton of the fingerprint as shown in Figure 6 since the ridges represent the dark curves shown in the original fingerprint images. The first primary component can be reconstructed at an average bit rate as low as 0.0234 bpp (i.e. compression ratio of 342:1). The second stage primary (ridge) component will require almost twice this bit rate. Also, the third stage reconstructed primary component will required almost three times that needed for the first stage. The average bit rate required to accumulatively encode the three stages data is on the average of 0.0662 bpp (compression ratio of 121:1).

(a) (b)

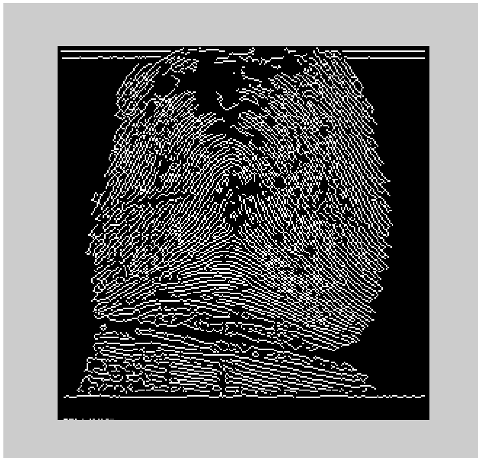
Figure 4. The original fingerprint images: (a) Sample (1), (b) Sample (2).

The unique set of features like end points and bifurcation points are extracted from the original fingerprint image by many methods [1]-[4]. In this paper, an approximation of the features can be found by taking the difference between the original fingerprint image and the difference (secondary) component. Figure 7 shows the secondary component, which is the difference between the original image and the 3rd stage reconstructed primary (ridge) component. This component is closely representing the binarized image. Figure 7 (a) and (b) show the original component before encoded. This component is filtered first by an optimal filter given in [15], and then decimated by 2. The VQ discussed in the previous section is used to encode this image. The reconstructed secondary (end and bifurcation points) are shown in Figure 7 (c) and (d) at 0.1206 and 0.192 bpp; respectively. It can be seen from this figure that the visual quality is almost the same as a result of using filters optimized for fingerprint image decomposition.

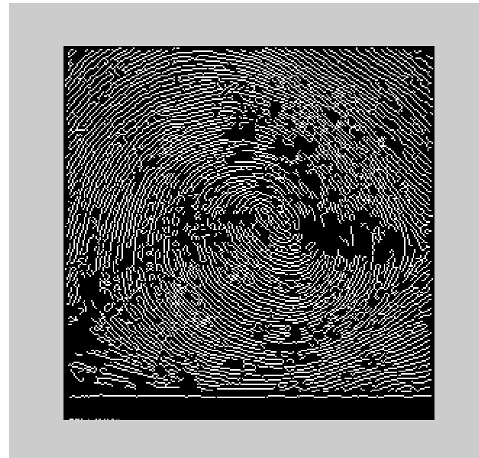
Table 1: The bit rate (bpp) and the PSNR (dB) for the three stages of the primary component.

| Stage Number | Fingerprint image | Bit rate (bpp) | SNR dB |
|---|---|---|---|
| 1St Stage | Sample (1)<br>Sample (2) | 0.0223<br>0.0245 | 10.765<br>9.621 |
| 2nd Stage | Sample (1)<br>Sample (2) | 0.0423<br>0.0531 | 14.26<br>13.28 |
| 3rd Stage | Sample (1)<br>Sample (2) | 0.0614<br>0.0771 | 16.27<br>14.55 |

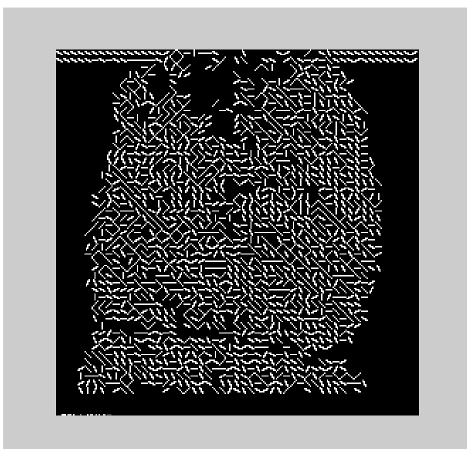
The fingerprint can be progressively reconstructed by sending first the primary components. Then, add to it the encoded secondary component. This is called progressive compression. Our experiments showed that the quality and compression ratio could be improved by applying more stages of the primary components. However, in this paper we apply three stages only for simplicity purpose. Figure 8 shows the reconstructed fingerprints at an average bit rate of 0.182 bpp and PSNR of 32.15 dB for Sample (1), and 0.179 bpp and PSNR of 30.8 dB for Sample (2). This will give an average compression ratio of 45:1



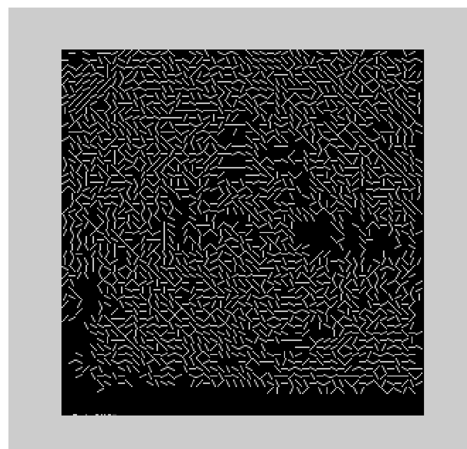
(a)



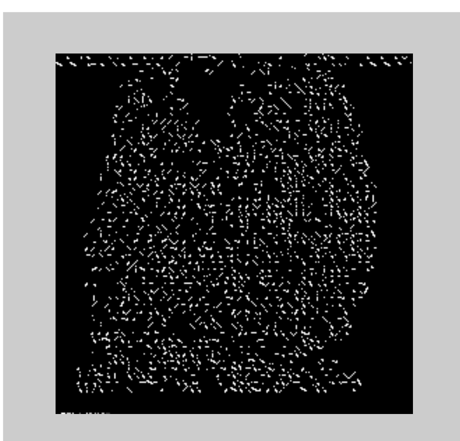
(b)



(c)



(d)

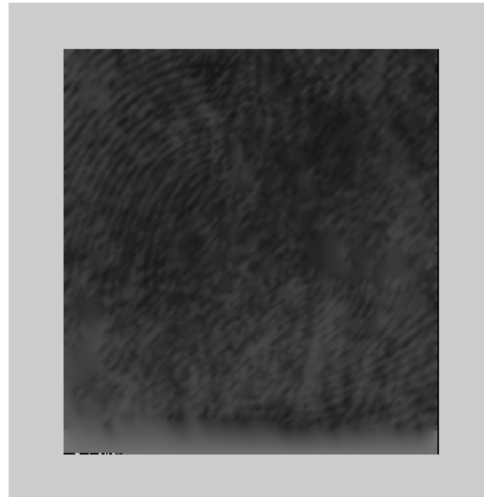


(e)

(f)

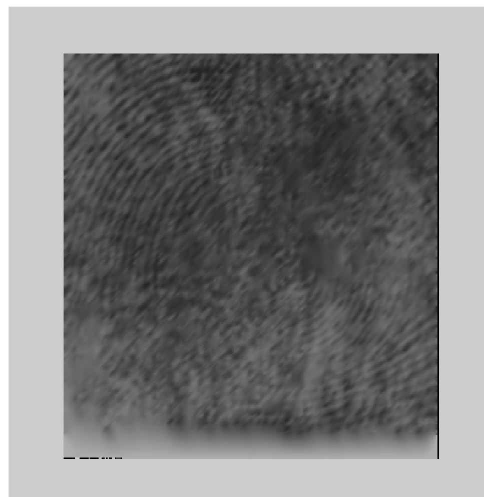
Figure 5. Canny edge detection for: (a) Sample (1), (b) Sample (2); Nameplates replacement for: (c) Sample (1), (d) Sample (2); Macro edge detection for: (e) Sample (1), (f) Sample (2).

(a)



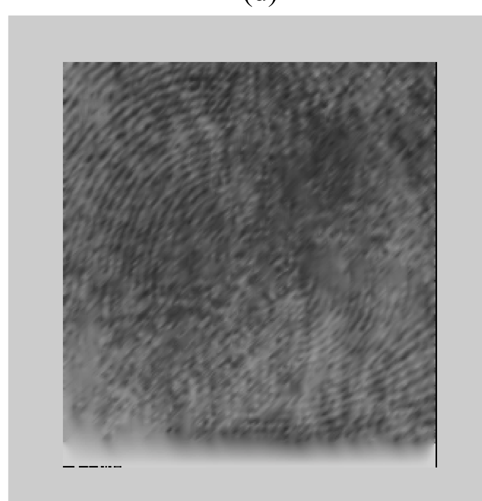
(b)

(c)



(d)

(e)



(f)

Figure 6. The 1st stage reconstructed fingerprint images: (a) Sample (1), (b) Sample (2). The 2nd stage reconstructed fingerprint images: (c) Sample (1), (d) Sample (2) . The 3rd stage reconstructed fingerprint images: (e) Sample (1), (f) Sample (2).

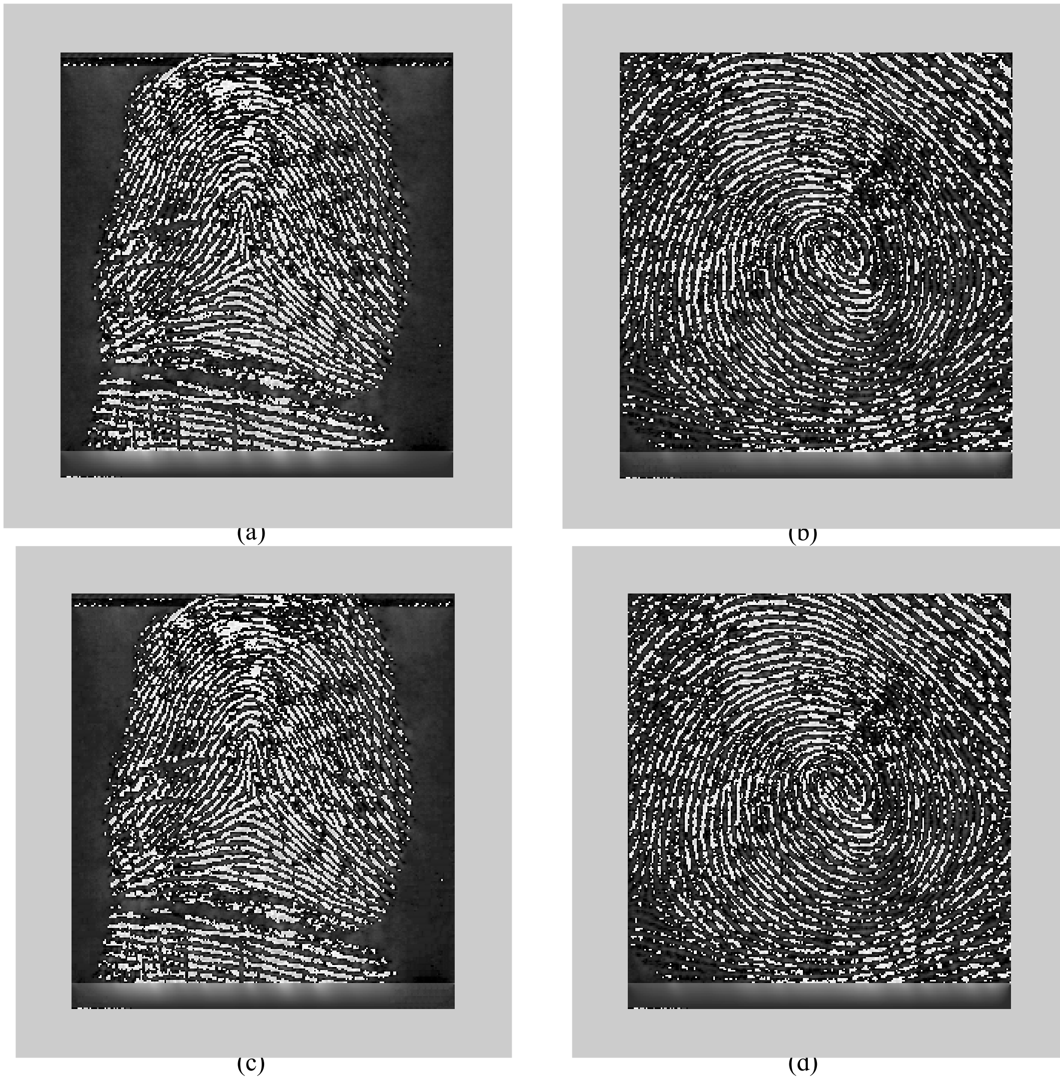


Figure 7. The secondary component for: (a) Sample (1), (b) Sample (2); The reconstructed component for: (c) Sample (1), (d) Sample (2).

## 5. CONCLUSION

In this paper, we have described a progressive hybrid approach for compressing fingerprint images, which based on the Canny edge detection method. Reconstruction is achieved by adding the compressed primary component to that of secondary component. We have suggested using the VQ and Huffman code to encode the nameplates of the ridge edges. The average compression ratio of the primary component depends on the number of ridge chain. To improve the visual quality and the compression ratio, ridges can be enhanced and simplified before adding it to the secondary component to eliminate false features and excessive data. This can be achieved by increasing the number of encoded stages for the primary component to be more than 3.

The main contribution of this work is to provide an algorithm, which exploits the structural properties of fingerprint images to achieve high compression ratio with good visual quality. The original structural properties such as the relative location of ridge endings and bifurcations are well preserved in the secondary component. The other contribution of the proposed scheme is to unify the advantages of both fingerprint data compression and fingerprint image compression algorithms existing in the literature.

The quality of the reconstructed images is competitive to the 0.75 bpp target bit set by FBI standard

[6]. Also, the compression ratio and the image quality of this algorithm is competitive to other existing methods given in the literature [7]-[9]. The compression ratio for our algorithm is about 45:1 (0.180 bpp).

(a) (b)

Figure 8. The reconstructed fingerprint images for: (a) Sample (1) at rate of 0.182 bpp and PSNR of 32.15 dB; (b) Sample (2) at rate of 0.179 bpp and PSNR of 30.8 dB.

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