A Hybrid Compression Technique for Segmented Hand Veins Using Quad Tree Decomposition

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Abstract—Biometrics are techniques for automatically identifying and authenticating an individual based on his physiological or behavioral characteristics. Hand vein is one of the biometric modalities. Hand vein check measures the shape and size of veins in the back of the hand in a grayscale image. In this paper, hybrid compression technique is applied on ninety hand vein images. This hybrid technique is combining the advantages of lossless techniques and lossy techniques. Only the essential information is selected and compressed using lossless technique, and nonessential information is compressed using lossy technique. The observed parameters are compression ratio (CR), total compression time (TCT), mean square error (MSE), and peak signal to noise ratio (PSNR). The goal is to maximize the CR while preserving images' information. This is achieved using object segmentation procedure and quad tree decomposition (QTD) as preprocessing steps for the compression process. Applying the hybrid technique on the dataset images results in a CR in the range of 89.56%.

Keywords—Discrete Cosine Transform; Hand Veins; Huffman Coding; Image Compression; Quad Tree Decomposition.

I. INTRODUCTION

Hand veins modality is used to verify individual identity based on the unique patterns of veins [1], [2]. Generally, the biometric images imply specific features such as uniform background, relatively large homogenous regions and high resolution [3].

In the proposed hybrid model, regions containing essential information is compressed using lossless algorithm, while other regions are compressed by lossy algorithm. This is achieved by segmenting hand veins as a preprocessing step (segmented regions), then using quad tree decomposition (QTD) function to compress the segmented regions, and to apply lossy compression technique on the other regions.

The data set consists of 90 images collected by Shahin [1]. The chosen parameters: compression ratio (CR), total compression time (TCT), mean square error (MSE), and peak signal-to-noise ratio (PSNR) are measured and the resulted compressed image is verified through Hand Vein Verification program [1].

CR is the ratio of the reduction in number of bits representing the digital image after compression to the number of bits representing the original digital image as shown in (1). It is the most significant metric of performance measure of a data compression algorithm. Lossless techniques yield modest CRs, while the lossy ones yield high CRs [4].

\[
CR = \frac{a-b}{a} \times 100. \tag{1}
\]

Where \(CR\) is the calculated compression ratio, \(a\) is the original image size and \(b\) is the compressed image size.

TCT is the time delay required for compressing and decompressing the image. TCT is one of the parameters that measure the performance of the compression algorithms. Complex compression algorithm requires relatively long time leading to serious problems in interactive applications [5].

PSNR is defined as shown in (2).

\[
PSNR = 10 \log_{10} \frac{255^2}{MSE}. \tag{2}
\]

Where \(MSE\) is defined as shown in (3).

\[
MSE = \frac{1}{XY} \sum_{i=0}^{X-1} \sum_{j=0}^{Y-1} [I(i,j) - I'(i,j)]^2. \tag{3}
\]

Where, \(X\) is the number of rows and \(Y\) is the number of columns of the image. \(I(i,j)\) is the original image pixels and \(I'(i,j)\) is the reconstructed image pixels.

The grayscale image pixels vary between 0 and 255 values. The PSNR is a quantitative measure for image quality evaluation [6], [7].

II. SYSTEM DESCRIPTION

The testing algorithm is done using Matlab operating on Windows XP. The dataset images are 8-bit per pixel grayscale images of type (BMP), as shown in Fig.1(a). Their dimensions are 320 * 240 pixels and so image size is 76 KB. The hand vein image consists of a hand grip containing veins and image background. Essential information in this image is the veins tree (identification network). Segmenting the veins is accomplished through five steps: background removal,
contrast stretching, smoothing, removing background illumination, and size thresholding. The image background is the darkest area in the image with grayscale level of 32 for all images. This grayscale level is determined by Try/Error method. By converting the image into a binary image, the hand grip is represented in white and image background in black, as shown in Fig. 1(b). The boundary points of the white area are allocated and the original image is cropped according to these extreme points resulting in an image containing the hand grip only as shown in Fig. 1(c).

The dynamic range is defined as the difference between minimum and maximum grayscale levels. As hand veins show wide dynamic range, it overlaps with the grayscale levels of other components in hand grip (hair and hand grip background). Contrast stretching is required to decrease these overlaps. The minimum grayscale of the veins is set to 0. The maximum grayscale of the veins is set to 255. The resulted image is shown in Fig. 1(d). Smoothing is applied to ensure continuity and homogeneity of the veins as shown in Fig. 1(e). An average filter is selected with a size small enough to match the width of the narrowest vein. The width of the narrowest vein is determined by checking the full dataset manually. As this dataset was acquired by the same camera in similar conditions, the dataset resolution does not change. So, the width of the narrowest vein does not change and the filter size will not be changed. The morphological close considers any components in the hand grip as gaps, and fills these gaps with the gray level of the hand grip background. Subtracting the background image from the smoothed one, resulted in an image showing the veins including noise (parts of the boundary of the hand grip), as shown in Fig. 1(f).

To remove these extra regions, the image is converted once again to a binary image as shown in Fig. 1(g). Size thresholding is performed to preserve all the veins areas to remove the nonessential small regions, as shown in Fig. 1(h). Multiplying the resulted binary image by the subtracted grayscale image, the segmented grayscale image containing the veins of the hand grip is obtained. Fig. 1(i) shows the segmented image.

A. Quad Tree Decomposition

The fundamental method for creating the QTD is the top-down approach that divides a square image into four equal sized blocks [8]. Each ‘parent’ block is investigated for homogeneity condition. If the block does not pass the homogeneity condition, it is subdivided into four equal sized ‘child’ blocks. Then applying homogeneity condition iteratively on ‘child’ blocks till it reaches preselected block size [4]. The QTD consists of successive non-overlapping subdivided blocks of the original image by a factor of four [9]. The homogeneity test is performed by measuring the dynamic range of each block. The dynamic range of the block is compared to a threshold. If the dynamic range is greater than the threshold, the block will be subdivided to four successive blocks. If the dynamic range is smaller than or equal the threshold, the block will be kept as it is. The QTD hierarchy results in an image with different sized blocks. The location of each block, and the grayscale levels of the components of each block are stored into a file, which then can be employed to regenerate the image [10].

B. Implementation

The image is adjusted to be a square image of size 256*256 pixels and the smallest block size is set to two. The QTD threshold is set to 2.3, which is the dynamic range for the veins in the segmented image. The QTD of the segmented image is superimposed on the original image as shown in Fig. 1(j). The position of the 2*2 blocks and the grayscale levels of the components of these blocks are stored into an array, which then can be employed to regenerate the image. Fig. 2 shows a flow chart of the hybrid compression process.

C. Lossy Compression of the Hybrid Process

Lossy compression is applied on the regions other than the hand veins regions. The used lossy compression technique is discrete cosine transform (DCT). DCT is used to reach a high CR as it is applied on nonessential areas. Zeros are set at the position of the 2*2 blocks to complete the image with a homogenous component. The image that will be compressed by DCT is shown in Fig. 3(a). The compressed file is decompressed using inverse discrete cosine transform (IDCT) to generate the reconstructed lossy image. The reconstructed lossy image is shown in Fig. 3(b).

D. Lossless Compression of the Hybrid Process

Lossless compression is applied on all the 2*2 blocks which represent the hand veins. There are two lossless compression techniques used in the hybrid process. Run length encoding (RLE) is used when all the grayscale levels in the block have equal values. RLE is used for its efficiency and simplicity. Huffman coding is used when the blocks have different grayscale levels. The final reconstructed image shows the hand veins with a perfect quality as it is compressed losslessly. The other regions in the image show deterioration in quality as they are compressed using lossy technique.

The final reconstructed image is shown in Fig. 3(c). The reconstructed image is matched with the original resized image using the hand vein verification system. The result of the matching process determines whether the reconstructed image is accepted or rejected. This test is applied on the 90 images which represent the data set.

III. RESULTS

Testing the proposed compression algorithm on 90 hand veins images, the mean results of observed parameters CR, TCT, MSE, and PSNR are as shown in Fig. 4.

IV. DISCUSSION

The mean of the CR is 89.56%. Fig. 5 shows the CRs of the sample set. The number of 2*2 blocks represents the regions of the image that will be compressed using lossless technique. The more 2*2 blocks in the image, the larger the losslessly compressed regions, the lower CR. The less 2*2 blocks, the higher the CR. Image 36 expresses the least CR with 83.63%
containing 4148 blocks of size 2. Image 86 expresses the most CR with 93.22% containing 2420 blocks of size 2. Fig. 6(a) shows the QTD of image 36. Fig. 6(b) shows the QTD of image 86.

The mean of the TCT is 6.97 second. The TCT of the lossy technique is less than half second. The TCT of the lossless technique represents mostly the TCT of the whole process. It has to be noted that the timings shown depend on the actual software being employed for compression which can significantly vary.

For high quality image, PSNR value should be as high as possible and MSE value should be as low as possible. The mean of the MSE is 19%. The MSE ranges from 13.79% to 25.16%. The mean of the PSNR is 35.37 decibel. The PSNR ranges from 34.12 to 36.74 decibel. It is observed that the PSNR values are varying in a narrow range because of the consistency of the hand vein modality.

Fig. 7 shows a reconstructed image without the preprocessing segmentation steps. It is clear that there are two drawbacks in this image. The hand grip boundary is compressed losslessly despite of being a nonessential area. There is a discontinuity in the veins which affects the verification process.

V. CONCLUSIONS

The separation of the compression technique applied on the veins from that applied on the other regions is the added value of this paper. The considered technique strives to reach a high CR without any deterioration in image quality. The technique has proved high efficiency by reaching a high CR and a high PSNR within reasonable time. It has been tested to be fully functional on ninety hand veins images. The most valuable point is the automatic segmentation of the hand veins and applying lossless compression technique on them. This point leads to the generalization of the technique on all dataset images. A compression factor of 4:1 or less is recommended for hand veins as reported in [11]. The considered technique accomplishes a compression factor of 9.58:1.

**Figure 1.** Applying preprocessing steps resulting segmented Hand Veins.

**Figure 2.** Flowchart of the proposed compression scheme.
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REFERENCES


