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Identification of Persons by Fingerprint Recognition and Verification using Minutiae Extraction Technique with Compression Technique

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Abstract Fingerprint identification and recognition is one of the most common biometric features used for personal recognition. There are many techniques used for finding the features of the fingerprint to manage the way to make it more dependable when matching it with other images of fingerprints. In this paper, the minutiae extraction technique has been used for fingerprint recognition and verification. Two types of compression techniques (Huffman compression code and Arithmetic compression code) have been used to improve the problem of the large size of the storage space of the database used for fingerprint images. Huffman compression technique was the most accurate technique for compression of fingerprint images due to the resulting of the factors of Compression Ratio (CR), Matched score (S), False Matching Ratio (FMR) and False Non Matching Ratio (FNMR), and that when the adaptive threshold has been used to improve the system.

Key Words— Arithmetic code compression, Compression ratio, False matched ratio, False non matched ratio, Fingerprint recognition and verification, Huffman code compression, Matched score.

I. INTRODUCTION

A fingerprint pattern is comprised of a sequence of ridges and valleys. In a fingerprint image, the ridges appear as dark lines while the valleys are the light areas between the ridges. A cut or burn to a finger does not affect the underlying ridge structure, and the original pattern will be reproduced when new skin grows. [1] Ridges and valleys generally run parallel to each other, and their patterns can be analyzed on a global and local level. At the global level, the fingerprint image will have one or more regions where the ridge lines have a distinctive shape. These shapes are usually characterized by areas of high curvature or frequent ridge endings and are known as singular regions. The three basic types of these singular regions are loop, arch, and whorl, examples of which are shown in "Fig.1" The matching algorithms we will use is he minutiae extraction, Compiled with two types of compression techniques which are (Huffman and Arithmetic) to find the best compression technique we can use depends on the outcome results.

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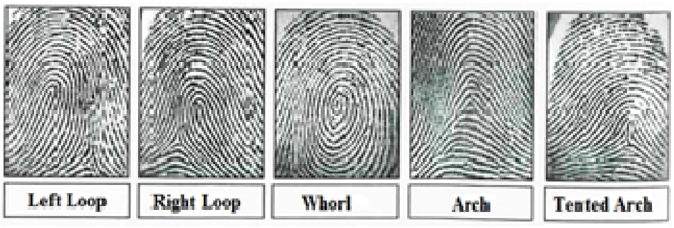


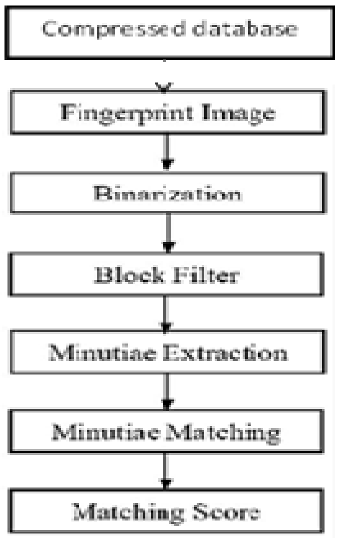
"Fig.1" Examples of fingerprint classes

II. METHODOLOGY

The proposed block diagram used in this paper as shown in "Fig.2" gives the block diagram of FRMSM (Fingerprint Recognition using Minutia Score Matching method) [2] which is used to match the test fingerprint with the compressed database using Minutia Matching Score.

The input fingerprint image is the gray scale image of a person, which has intensity values ranging from 0 to 255. In a fingerprint image, the ridges appear as dark lines while the valleys are the light areas between the ridges.

Minutiae points are the locations where a ridge becomes discontinuous. A ridge can either come to an end, which is called as termination or it can split into two ridges, which is called as bifurcation. The two minutiae types of terminations and bifurcations are of more interest for further processes compared to other features of a fingerprint image.



"Fig.2" Block Diagram of FRMSM

III. BASE THEORY

Minutiae extraction. In the binary image based method, the binarization of the gray-scale image is the initial step. [3] This requires each gray-scale pixel intensity value to be

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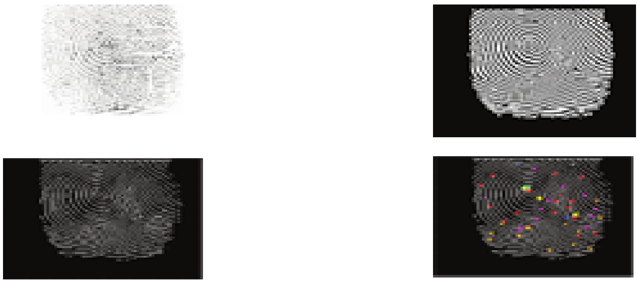
transformed to a binary intensity of black (0) or white (1). The simplest approach is to apply a global threshold where each pixel is mapped according to:

$$I(x,y) = \begin{cases} 1 & \text{if } I(x,y) \geq t, \\ 0 & \text{otherwise.} \end{cases} \quad (1)$$

This method is usually not adequate since fingerprint images may have differing levels of contrast throughout the image. However, the same method can be applied with locally adaptive thresholds. "Fig.3"



"Fig.3" Minutiae Extraction steps

Top left: Original gray-scale image.

Top right: binary image.

Bottom left: inverted skeleton (thinned) image.

Bottom right: inverted skeleton image with core point (green),

Delta/lower core points (gold),

Bifurcations (blue for θ∈ [0°- 180°)

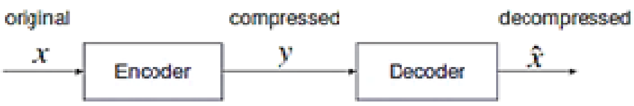
And purple for θ ∈ [180°- 360°),

And ridge endings (orange for θ ∈ [0°- 180°)

And red for θ ∈ [180°- 360°).

IV. BASIC DATA COMPRESSION CONCEPTS

As shown in "Fig.4" the compression process [4] can be described as:



"Fig.4" Block diagram for the compression process

- Lossless compression $x = \hat{x}$
  - Also called entropy coding, reversible coding.
- Lossy compression $x \neq \hat{x}$
  - Also called irreversible coding.
- Compression ratio = $|x|/|y|$
  - $|x|$ is number of bits in x.

V. HUFFMAN CODING TECHNIQUE FOR IMAGE COMPRESSION

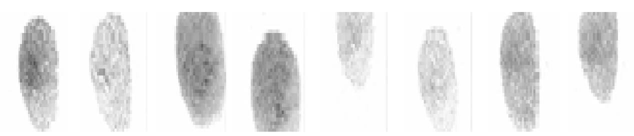
Proposed by DR. David A. Huffman in 1952. A method for the construction of minimum redundancy code. Huffman code is a technique for compressing data. Huffman's greedy algorithm looks at the occurrence of each character and it as a binary string. In an optimal way. Huffman coding is a form of statistical coding which attempts to reduce the amount of bits required to represent a string of symbols. The algorithm accomplishes its goals by allowing symbols to vary in length. [5] Shorter codes are assigned to the most frequently used symbols, and longer codes to the symbols which appear less frequently in the string (that's where the statistical part comes in). Code word lengths are no longer fixed like ASCII .Code word lengths vary and will be shorter for the more frequently used characters. Huffman compression belongs into a family of algorithms with a variable code word length. That means that individual symbols (characters in a text file for instance) are replaced by bit sequences that have a distinct length. So symbols that occur a lot in a file are given a short sequence while other that are used seldom get a longer bit sequence. [6]

VI. ARITHMETIC CODING TECHNIQUE FOR IMAGE COMPRESSION

Is a data compression technique that encodes data (the data string) by creating a code string which represents a fractional value on the number line between 0 and 1. The coding algorithm is symbol wise recursive; i.e., it operates upon and encodes (decodes) one data symbol per iteration or recursion. [7] On each recursion, the algorithm successively partitions an interval of the number line between 0 and 1, and retains one of the partitions as the new interval. Thus, the algorithm successively deals with smaller intervals, and the code string, viewed as a magnitude, lies in each of the nested intervals. The data string is recovered by using magnitude comparisons on the code string to recreate how the encoder must have successively partitioned and retained each nested subinterval. Arithmetic coding differs considerably from the more familiar compression coding techniques, such as prefix (Huffman) codes.
Also, it should not be confused with error control coding, whose object is to detect and correct errors in computer operations. [8]

VII. EXPERIMENTS AND PERFORMANCE EVALUATION

In this section we will discuss the results which we get when we execute the Matlab code to define the matching score between the images in the database used which consists of 64 images formed in TIFF image format (Tagged Image File Format). Those 64 images are divided into 8 main fingerprints images each one of them has 8 sub images for the same fingerprint but in a different orientations and scanned regions also the differences in purity. As shown in "Fig.5"



"Fig.5"Sample of one group of the main eight images used in the applied database

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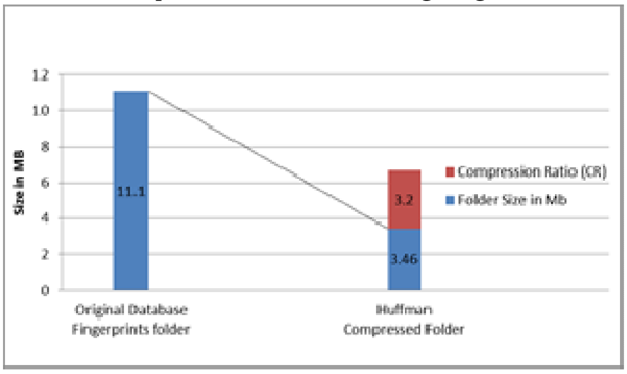
VIII. APPLYING THE COMPRESSED DATABASE TO THE SYSTEM USING HUFFMAN COMPRESSION TECHNIQUE

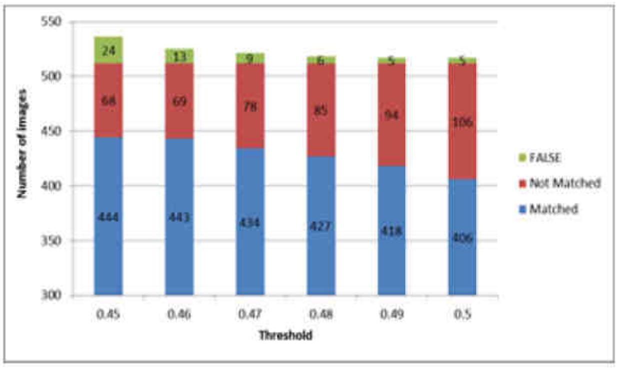
The original used data base folder size = 11.1 MB
The compressed database folder size = 3.46 MB
The compression ratio CR = $\frac{11.1}{3.46} = 3.2$
That can be represent with the following "Fig.6"



"Fig.6" The difference between the original database folder size and the compressed file size using Huffman technique

We found the results using the Huffman compression technique at different threshold than 0.48 to find how it can change the matching ratio MR to find the best result.

So we get the results at the values of threshold = (0.45, 0.46, 0.47, 0.48, 0.49 and 0.5) and that will be shown in the "Fig.7"

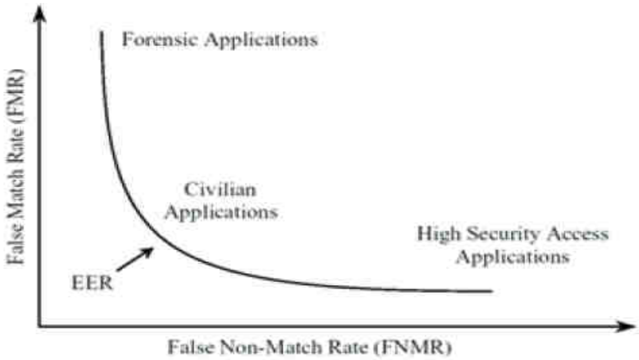


"Fig.7" Results of Matched, Not matched and False fingerprint images when using Huffman compression technique at different thresholds

IX. RELATION BETWEEN FNMR AND FMR

Equal-Error Rate (EER) [9] denotes the error rate at the threshold t for which false match rate and false non-match rate are identical:

FMR(t) = FNMR(t). In practice, because the matching score distributions are not continuous (due to the finite number of matched pairs and the quantization of the output scores), an exact EER point might not exist. In this case, instead of a single value, an interval should be reported [10]. Although EER is an important indicator, in practice, a fingerprint-based biometric system is rarely used at the operating point corresponding to EER, and often a more stringent threshold is set to reduce FMR in spite of a rise in FNMR. As shown in "Fig.8"



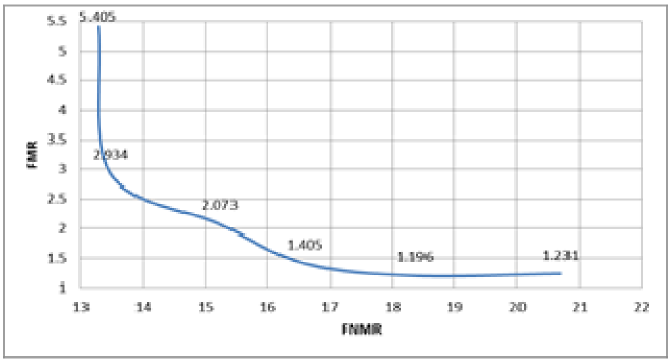
"Fig.8" Typical operating points of different applications

That difference in results will lead us to find the FMR, the FNMR and the MR at each value of the above thresholds showed in (Figure 7). That will be shown in (Table 1).

Table 1. The different values of FMR, FNMR and MR at the difference value of thresholds

Threshold	FMR	FNMR	MR
0.45	5.405%	13.281%	86.718%
0.46	2.934%	13.476%	86.523%
0.47	2.073%	15.234%	84.765%
0.48	1.405%	16.601%	83.398%
0.49	1.196%	18.359%	81.640%
0.50	1.231%	20.703%	79.296%

The relation between FNMR and FMR at the difference thresholds which lead to decide the suitable threshold we will use due to the application we will apply the system as we will show in "Fig.9"



"Fig.9" Relation between FNMR and FMR

X. APPLYING THE COMPRESSED DATABASE TO THE SYSTEM USING ARITHMETIC COMPRESSION TECHNIQUE

The original used data base folder size = 11.1 MB
The compressed database folder size = 4.5 MB
The compression ratio CR = $\frac{11.1}{4.5} = 2.46$
As shown in "Fig.10"

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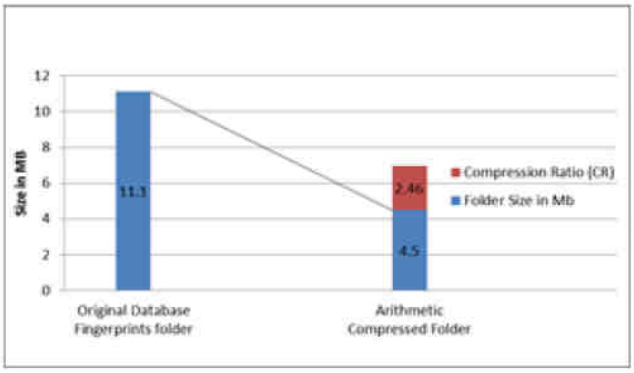
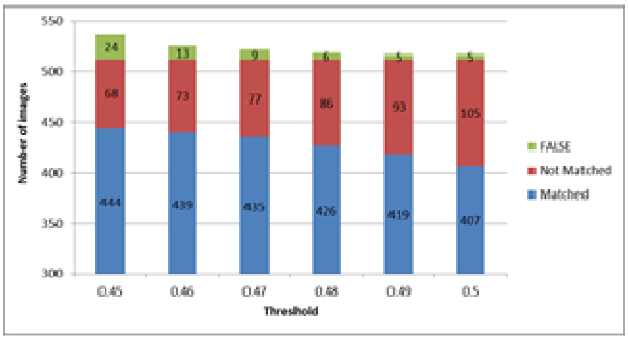


"Fig. 10" The difference between the original database folder size and the compressed file size using Arithmetic technique

We found the results using the Arithmetic compression technique at different threshold than 0.48 to find how it can change the matching ratio MR to find the best result.

So we get the results at the values of threshold = (0.45, 0.46, 0.47, 0.48, 0.49 and 0.5) and that will be shown in the "Fig.11"



"Fig.11" Results of Matched, Not matched and False fingerprint images when using Arithmetic compression technique at different thresholds

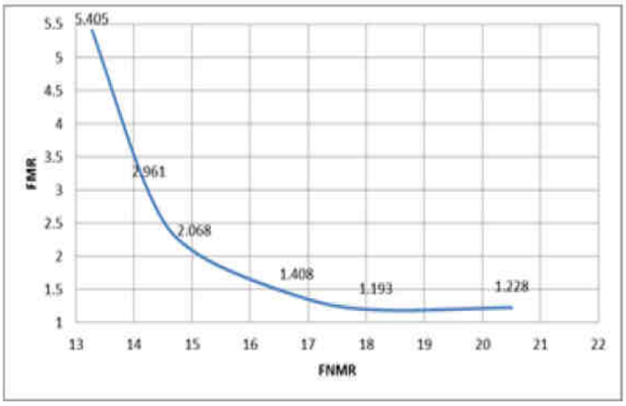
That difference in results will lead us to find the FMR, the FNMR and the MR at each value of the above thresholds. That will be shown in (Table 2).

Table 2. The different values of FMR, FNMR and MR at the difference value of thresholds

Threshold	FMR	FNMR	MR
0.45	5.405%	13.281%	86.718%
0.46	2.961%	14.257%	85.742%
0.47	2.068%	15.039%	84.960%
0.48	1.408%	16.796%	83.203%
0.49	1.193%	18.164%	81.835%
0.50	1.228%	20.507%	79.492%

The relation between FNMR and FMR at the difference thresholds which lead to decide the suitable threshold we will use due to the application we will apply the system.

As shown in "Fig.12"



"Fig.12" Relation between FNMR and FMR

XI. ADAPTIVE THRESHOLD

Related to (Equation 2) that is:

$$sm = \sqrt{\frac{n^2}{N1 \times N2}} \quad (2)$$

Where, (Sm) is the similarity measured matched score between the current fingerprint image under test and the new fingerprint image stored in the database.

(n) is the number of matched minutiae founded between the current fingerprint image under test and the new fingerprint image stored in the database.

(N1) is the number of founded minutiae in the current fingerprint image under test.

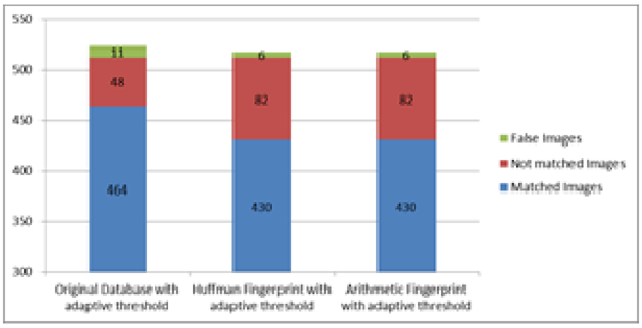
(N2) is the number of founded minutiae in the new fingerprint image stored in the database.

We found that if we try to have a threshold related to the most effected value in (Equation 2) which is N1 then we can find an adaptive threshold can vary every time we try to match a new fingerprint image with the stored images in the database.

After many trials to find a suitable form for that adaptive threshold and much more trying to get the best results, we finally found this statement (Equation 3):

$$\text{Adaptive threshold} = 0.44 + \frac{N1}{1000} \quad (3)$$

Where (N1) is the number of founded minutiae in the current fingerprint image under test. Then we apply that adaptive threshold to the system to be executed, and we found the following results. Results of the adaptive threshold as shown in "Fig.13"



"Fig.13" Results with adaptive threshold

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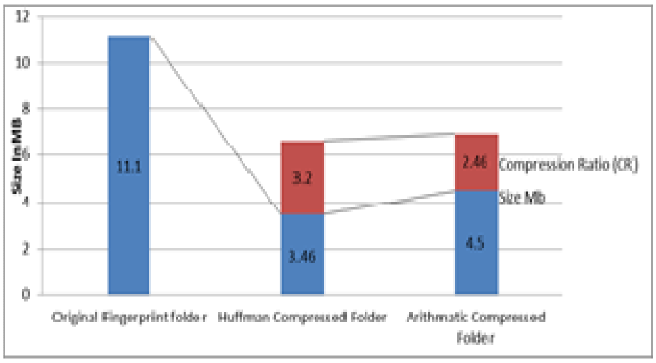
We can find for each case the FNMR, FMR and MR as shown in (Table 3)

Table 3. The different values of FMR, FNMR and MR at the adaptive thresholds

Method	FMR	FNMR	MR
Original database	2.370%	9.375%	90.625%
Huffman database	1.395%	16.015%	83.984%
Arithmetic database	1.395%	16.015%	83.984%

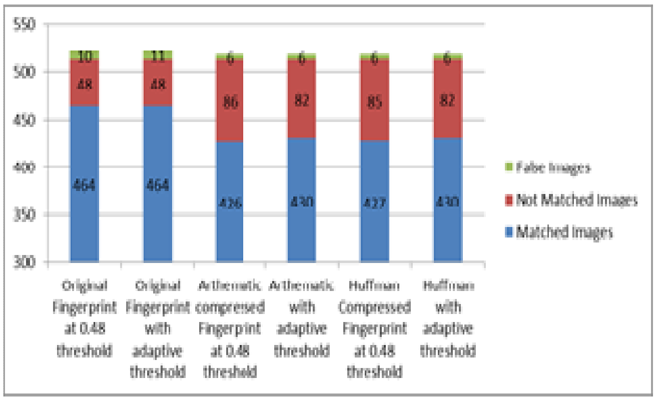
XII. COMPARISON BETWEEN RESULTS

The difference between the sizes of database in MB in each method will be shown in "Fig.14"



"Fig.14" The difference between the sizes of database in MB in each method.

Results of Matched, Not matched and false fingerprint images when using adaptive threshold technique can be shown in "Fig.15"



"Fig.15" Matched, Not matched and false fingerprint images

XIII. CONCLUSIONS

This work represents a study to design a system to making a fingerprint identification and recognition using a compressed database for fingerprint images. We used the fingerprint minutiae extraction algorithm to process the step of Identification and recognition for the fingerprint images, and then we use two compression techniques to compress the database images of fingerprints. Those techniques are Huffman compression technique and Arithmetic compression technique. We get the results of each case at different selected thresholds also at a simple adaptive threshold.

We found that the best results is when we use the Huffman compression technique with the adaptive threshold due to the values of FNMR, FMR and MR also because of the Huffman compression techniques has the best compression ratio (CR) which is decrease the size of the used database to more than one third. and that achieves one of the most important goals of this paper which is decreasing the size of the storage space of the used fingerprint database, that will be most efficient in case of use in an enrollment system of a multinational companies, Also in case of archiving the database for fingerprints of a population in a large countries.

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