A Survey on Fingerprint Recognition Methods

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Abstract – Matching finger prints is the most popular biometric technique used for providing authentication. Fingerprint recognition systems scans for raw image, performs little preprocessing, features are extracted as vectors and stored in fingerprint databases. A review on various aspects of fingerprint recognition systems is presented in this paper. The paper briefs various types of fingerprint patterns, followed by minutiae based approach. Fingerprint ridges called minutiae are able to capture the invariant and discriminatory information present in the fingerprint images. Pattern recognition based approach is also studied followed by wavelet based approaches. The challenges and issues relating to fingerprint recognition system are critically reviewed in this paper. It is important for fingerprint recognition system to use good quality, noise free fingerprint image as input to achieve high accuracy. Various fingerprint image enhancement techniques were also analyzed and discussed in this paper.

Index Terms – Authentication, Biometrics, Fingerprint, Minutiae, Recognition, Wavelet.

1. INTRODUCTION

Fingerprint recognition is the automatic technique of identifying the identification of an man or woman based totally on evaluation of stored fingerprint statistics with enter fingerprint records. It is one of the maximum widely known biometrics, used for authentication on laptop structures. Fingerprints are the impressions/ patterns available in human finger. With the age, those impressions get super but the systems do now not change over the time [2].

There exist a number of benefits which makes fingerprint reputation techniques famous. One largest gain is that it is very well typical inside the prison community. It is the value powerful, sort, dependable and most handy manner to perceive someone Fingerprint recognition is widely conventional as noticeably accurate approach of authentication since the danger of human beings same finger prints are scarce4.

Fingerprints cannot exchange unless there may be a bodily disturbance consisting of accidents or works in an industry with caustic or warm substances which may additionally harm fingerprints [5-6]. This is extremely beneficial. For instance, if dad and mom accumulate fingerprints of their youngsters and put it in a report and if they may be kidnapped, early life fingerprints can be used to make a match whilst they are diagnosed at later degree.

Automated fingerprint popularity systems are having positive pitfalls. It can also on occasion require not simplest fingerprint however additionally a legitimate pin, which can be extra tough to use than conventional structures. Sometimes false rejection may take place when the finger print reputation system fails to check in a person's fingerprint. This is known as type I error7. Sometimes fingerprint recognition gadget can also pick out a incorrect individual at some point of authentication procedure main to unauthorized get entry to furnish. This is referred to as kind II error [7]. Hence an excellent finger print popularity gadget must overcome type I and sort II errors and it must additionally be correct.

2. TYPES OF FINGERPRINT PATTERENS

The patterns on fingerprint are broadly classified into three categories.

- Arches.
- Loops.
- Whorls.

2.1. Arches

Fingerprint patterns where the ridges run from one side to the other side without any turn. Generally there is no delta in an arch pattern whenever there is a delta point, no re-curving ridge intervenes between core and delta points8. There exist four types of arches namely:

- Plain Arches.
- Radial Arches.
- Tented Arches.
- Ulnar Arches

2.2. Loops

Patterns in which the ridges flows inwards and returns in the direction of the origin. Ridge senter in either side of the impression, re-curves and terminates in the direction of the side where ridges entered. There are four types of loops.

- Plain Loop.
- Lateral Pocket Loop.

- Central Packet Loop.
- Twinned Loop.

2.3. Whorls

Patterns in which ridges form circularly around a central point. Any pattern that contains two or more delta points is whorl patterns. There are four types of whorl patterns.

- Plain Whorls.
- Central Pocket Loop Whorls.
- Double Pocket Loop whorls.
- Accidental Whorls.

Figure 1. Arches.

Figure 2. Loops

Figure 3. Whorls

3. EXISTING METHODS

3.1. Minutiae based Approach

In biometrics and forensic sciences, minutiae talk to precise factors in a fingerprint. They are the foremost capabilities which might be used to compare one sample with another [9]. It includes ridge bifurcation or ridge finishing on a finger print. Detected minutia in a fingerprint pattern is identified with the aid of a fixed of attributes such as minutia position, minutia route and sort along with bifurcation or finishing. Thus a finger print is represented with the aid of a set of minutia present in the fingerprint pattern [10]. Fingerprint can be verified via evaluating trivia points present in two images. Minutia is saved as the composition of attribute values together with minutia role within the fingerprint pattern10**.** Minutia based fingerprint reputation structures are one a number of the popular strategies which achieves very excessive accuracy. It consists of four steps and they are

- Orientation field estimation.
- Ridge extraction.
- Minutia extraction.
- Post processing.

Accurate illustration of a fingerprint pattern relies upon on accurate extraction and storing of minutia records gift inside the fingerprint picture. And also accurate representation of finger print sample is essential due to the fact many business huge-scale structures are dependent on fingerprint recognition structures. A minutia factor is recognized as follows:

If the brightness cost of a pixel is transposed, ridge endings end up bifurcational and vice-versa. The function of the minutia is the tip of the ridge or valley. Minutia extraction techniques can be broadly categorised as binarized fingerprint snap shots and gray scale fingerprint images [11]. Under the binarized fingerprint images, unthinned binarized photographs, thinned binarized image, chain code based totally, run illustration based totally, ridge float and local pixel based, crossing variety based totally and morphology based techniques are available. Under gray scale fingerprint snap shots, we've got ridge line glide based totally and fuzzy based totally methods [11]. As said in advance, trivia primarily based finger print recognition systems achieves excessive accuracy. However it has the subsequent drawbacks

- Corrupted or noisy images (images with arti facts)
- cannot be used with finger print recognition systems. High quality fingerprint images are used.
- Minutiae based approaches are slow for real time applications.

3.2 Pattern Recognition Approach

Fingerprint includes composition of ridges and valleys referred to as styles. Pattern recognition methods use patterns for authentication. Pattern reputation is implementing identities of enter facts by spotting patterns it includes and relationships it maintains [12]. Pattern popularity methods are extensively categorised as decision theoretic and structural. Quantitative descriptors inclusive of vicinity, length and textures are used to describe a sample beneath selection theoretic approach. Relationships of several descriptors are used to explain a pattern below structural method. The vital requirement on this type of fingerprint popularity gadget is to locate the pleasant descriptors that could represent a pattern in a great way [12]. Pattern based fingerprint recognition system works with the aid of generating the data, where input is generated. Pre processing is done in order that image will become smooth and unfastened from noise. Next, functions are extracted and stored as feature vector. Whenever enter parameters are furnished, they may be matched with Feature Vector database and based on the outcome, authentication is granted or rejected [13]

3.3 Wavelet based Approaches

Wavelet transforms may be used on fingerprint patterns to provide authentication. Wavelets reduce information into distinctive frequency additives and each element is studied with a resolution matched to its scale [14]. In this kind of technique, fingerprint images are decomposed the usage of Discrete Wavelet transform. Three stages of decomposition of fingerprint images are achieved for schooling. The mathematical tools like suggest and popular deviation are also used at some point of decomposition process [14]. For fingerprint class, patterns are rotated from zero to 360 degrees and 10 ranges are extended in every step. Set of wavelet statistical values and co-incidence matrix functions are extracted. It is apparent that directional resolving strength of wavelets extracts texture facts in LL, LH, HL and HH diagonal instructions. Moreover, wavelet based fingerprint recognition structures does no longer require fingerprint photo pre processing or publish processing. Hence they may be fast whilst compared to trivialities based totally procedures. Another advantage of wavelets is that it performs minimal three degree of texture decomposition which makes automated fingerprint popularity device accurate. This is the weak spot of most of the texture evaluation schemes because the picture is analyzed at single scale.

4. CHALLENGES IN FINGERPRINT RECOGNITION

Performance of any fingerprint popularity device heavily is based on great of finger print photograph. Quality of a fingerprint photo is ruled by using elements such as pores and skin conditions, sensor situations, poor consumer cooperation, etc. Few elements may be prevented whereas few vary over a time. Hence lack of robustness is an important trouble in fingerprint recognition systems [16]. It is higher to reject degraded snap shots in the course of training so that overall performance of fingerprint recognition gadget may be maintained.

Another problem in fingerprint reputation system is the usage of multiple sensors. Different sensors interpret and represent fingerprint image in a different way [17]. Changing the sensors might also affect the overall performance of the fingerprint reputation systems. It may be an amazing idea to represent fingerprint images underneath a commonplace exchange layout. Another manner with the aid of which this hassle may be averted is to normalize the uncooked information and extracted features. Apart from advantages of fingerprint popularity structures, they may be also goals of attacks. Unfortunately, fake enter to biometric popularity structures proved to be successful. Matching rating (threshold cost) is a pivotal element in fingerprint reputation systems. Additional challenges encompass matching fingerprints which can be affected with plastic distortions. Classification technique for efficient seek of fingerprints in a fingerprint database is also a largest challenge [17].

5. FINGERPRINT ENHENCEMENT

To make photo clean for better utilization by fingerprint popularity structures, it's far vital to enhance fingerprint photograph. Generally fingerprint photograph is complete of noise as human hands are frequently comes in contact with most of the guide duties and becomes creased, grimy, moist, dry, cut, worn, and so forth. Purpose of image enhancement is to remove noise from fingerprint images so that ridges against valleys are truly seen. Image enhancement strategies are widely labelled as spatial domain techniques and frequency domain techniques.

Spatial area techniques immediately deal with photograph pixels. In frequency area methods, Fourier remodel of an image is acquired. All the necessary photo enhancement processes are applied on Fourier rework of the photograph. Finally, inverse Fourier remodel is implemented to get the consequent image18. Few fingerprint enhancement strategies under spatial domain and frequency domain are discussed below:

5.1. Histogram Equalization

Histogram equalization is mainly used to adjust image intensities to enhance contrast of the whole image. Histogram is the graphical representation of relative frequency of various gray levels available in an image19. By equalizing the histogram, we can improve the contrast of an image. It’s a type of spatial domain technique and it is widely accepted technique in image enhancement [19].

5.2. Fourier Transform

Fourier transform is an important mathematical tool used to decompose an image into sine and cosine components.

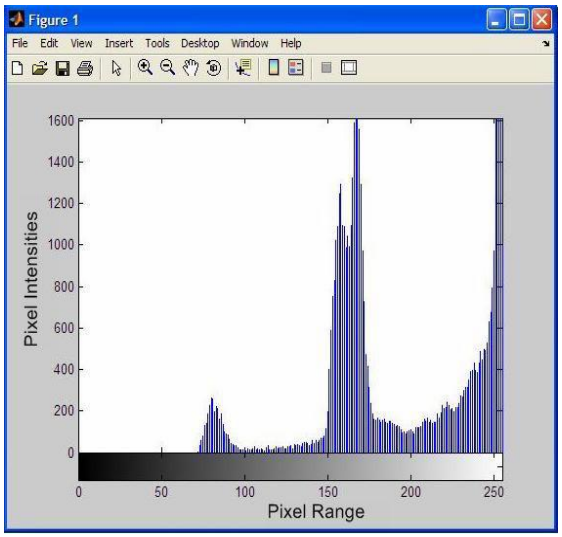

Figure 4. Histogram Figure.

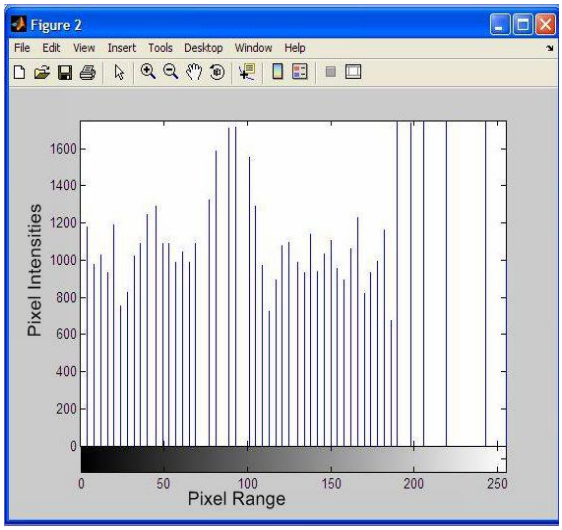

Figure 5. Equalized Histogram.

The basic idea here is to divide the fingerprint image into small processing blocks and enhance each block independently [20]. To decompose an image into blocks, the following formula is used:

$$F(u,v) = \sum_{i=0}^{m-1} \sum_{j=1}^{n-1} f(i,j) \times \exp\{-k2\pi \times \frac{u_i}{m} + \frac{v_j}{n}\}$$

for u = 0,1,2,…31 and v=0,1,2,3…31

Now each block is enhanced according to some formula. For example,

$g(x,y) = F\text{-}1\{F(u,v)+|F(u,v)|k\}$

where is $F\text{-}1\{F(u,v)\}$ represented by

$$f(x,y) = \sum_{x-0}^{n-1} \sum_{y-0}^{n-1} F(u,v) \times \exp\{j2\pi \times \frac{u_x}{m} + \frac{v_y}{n}\}$$

5.3. Filtering Methods

Filters are specially used to suppress both excessive frequencies or low frequencies in an photo. Filtering excessive frequencies within the image makes output picture easy and limiting low frequencies enhances or detects edges in an picture. Filtering idea work in each frequency domain and spatial domain. Different types of filters are available which are properly suited for fingerprint image enhancements.

Median filtering is used to eliminate salt and pepper type noise. Median price of all the pixels in a window is calculated and this fee is changed with pixels across the window [21]. Median filtering arranges pixel values of the window in an order and then choosing the median cost among those pixels.

High bypass filtering is used to extract edges of the image. High pass filtering sharpens the brink of the image. To attain this, a fraction of excessive bypass filtered image is added to the unique photograph. This is the primary idea for most of the photo polishing fashions. High skip filters tend to hold excessive frequency facts even as decreasing low frequency information [21]. The power of high pass filters is that it increases the brightness of the centre pixel relative to neighbouring pixel.

Directional filtering is likewise used for facet detection. Edge of an image is made seen if there is a massive exchange with a pixel to its adjoining pixel. This change is measured by means of first derivatives and directional filters compute first derivatives of an image [22]. Directional filters can be designed to compute first derivatives in any course.

Another technique used to hit upon edges of an photograph is the use of Laplacian filters. Laplacian filters are used to compute second derivatives wherein as directional filters compute first derivatives. Second derivatives constitute the rate of change of first derivative. This helps to determine whether or not the adjacent pixel values are edges or non-stop progression [22].

5.4 Comparison of Various Fingerprint Image Enhancement Techniques

Matching algorithms does no longer have any trouble in matching exact first-rate finger print photographs. But if the image fine is low, it's far an trouble for fingerprint matching set of rules and in this situation, fingerprint image enhancement is compulsory. There are various fingerprint picture enhancement strategies to be had with few working underneath spatial domain and few in frequency area. The below table presents contrast of numerous fingerprint photograph enhancement techniques. Fingerprint popularity systems works with the aid of obtaining character's fingerprints from scanner. This is the uncooked facts (image). Next some amount of pre processing is executed at the raw photograph so that the output image is nicely appropriate for characteristic extraction. Pre processing

includes fingerprint enhancement and filtering. Features are extracted from fingerprint pictures and stored as function vectors in fingerprint database. Finally matching is executed with input fingerprint with saved ones. The accuracy of a fingerprint popularity device is measured by using the following parameters.

False Acceptance Rate (FAR) is the measure that

- fin• gerprint recognition system wrongly allows access to the unauthorized users. It is defined as the ratio of number of false acceptances divided by the number of identification attempts.
- False Rejection Rate (FRR) is the measure that finger• print recognition system wrongly rejects access to the authorized users. It is defined as the ratio of number of authentic images not divided by the total number of authentic images.
- False Matching Rate (FMR) is the number of imposter • comparisons with threshold value 'T' divided by the total number of imposter comparisons.
- False Non Matching Rate (FNMR) is the number of • genuine comparisons with threshold value 'T' divided by the total number of genuine comparisons.
- Equal Error Rate (ERR) is the best single descriptor of • error rate of a biometric algorithm. ERR is the value where FMR and FNMR values are equal.

6. CONCLUSION

In this paper, an elaborate literature on fingerprint recognition systems has been studied. Fingerprint recognition system is a widely used biometric approach having applications like criminal investigations, terrorist identifications and other security issues. Fingerprint is a physiological biometric feature used to identify a person. Fingerprint does not change unless there is some physical disturbance such as accidents or works in an industry. These impressions become notable over the age and the chance of two people having identical fingerprints is rare. A good quality, noise free fingerprint image is the real need for fingerprint recognition systems to achieve robustness and accuracy. It is important to concentrate more on fingerprint image enhancement techniques.

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Method	**Advantages**	**Disadvantages**
Histogram Equalization	This method directly works on fingerprint image pixels	This method is discriminate and it can increase the background noise also
Band Pass Filtering	Removes noise and maintains true structures and ridges of fingerprint	This method fails if the input image contains heavy noise
Gabor Filtering	It combines the features of anisotropic filter and low pass filter to give high efficiency	This method fails to perform if the regions of the input image are tainted with heavy noises
Binarization and Thinning	This method preserves the connectivity of the ridges and features of the fingerprints that do not get distorted	Sometimes this method may yield non-connected or even empty medial lines in fingerprint images
2D Fourier Transform	This method is computationally fast and effective in de-noising fingerprint images	Lack of shift variance and poor directional selection of diagonal features because wavelets are separable

Table 1. Comparison of survey