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A Survey on Fingerprint Recognition System

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***Abstract*—** Fingerprint Matching is a prevailing biometric technique used for providing authentication. In Fingerprint recognition systems a raw image is scanned, then pre-processing is performed, features are extracted as vectors and stored in fingerprint databases. In this paper, a review of different features of fingerprint recognition systems is presented. A brief of different types of fingerprint patterns followed by minutiae based approach is given in this paper. The invariant and discriminatory information present in the fingerprint images are captured using fingerprint ridges known as minutiae. 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. A good quality, noise free image should be used as input in fingerprint recognition system to achieve high accuracy. Different fingerprint image enhancement techniques are also analyzed and discussed in this paper.

***Keywords*—** Authentication, ,Recognition, Biometrics, Fingerprint, Minutiae.

I. INTRODUCTION

The automatic technique of the identification of a man or woman based totally on evaluation of stored fingerprint statistics with enter fingerprint records is called Fingerprint recognition[1]. It is one of the widespread biometrics which is used for authentication on laptop structures. Recognition of Individuals identity can be confirmed based on "who individual is", rather than by "what individual possesses"using their physiological traits like fingerprints[2]. A Fingerprint is the impression or pattern available in human finger.

The Biometric information is very useful as information like fingerprint can be used in place of passwords identity verification of users. Hence privacy can be improved both for user and admin[3].

There are numerous benefits which have made this technique popular. One of the main application is in prison community.It is the valuable, powerful and most handy manner to perceive someone. The case of two human beings having same fingerprints is rare[4].

Fingerprints are not changed unless there is a change in body like accidents or working in an industry with caustic or warm substances which leads to harming fingerprints [5][6].

The motive is to study the different types of fingerprint recognition systems , their challenges and applications.

Automated fingerprint recognition systems have some drawbacks. It can also be an occasion that it requires not only a fingerprint but additionally a legitimate pin, which can be extra tough to use than conventional structures. Sometimes false rejection may take place when the fingerprint recognition system fails to check in a person's fingerprint. This is known as type I error [7]. Sometimes fingerprint recognition system can also pick out an incorrect individual at some point of authentication procedure leading to an unauthorized entry. This is referred to as kind II error [7]. Hence an excellent fingerprint recognition system must overcome type I and sort II errors and it must be correct.

II. RELATED WORK

In 2002 A.L.H. Jin A. Chekima J.A. Dargham presented a paper that presented a fingerprint identification and recognition system using backpropagation neural network[8].

In 2009 H. Xu, Raymond N.J. Veldhuis, Tom A.M. Kevenaar, Ton A.H.M. Akkermans presented a paper that focussed on the performance of the spectral minutiae fingerprint recognition system[9].

In 2010 Le Hoang Thai 1 and Ha Nhat Tam proposed a paper that discussed on the standardized fingerprint model that is used to synthesize the template of fingerprints[10].
In 2010 Ramaswamy G, Sreenivasarao V, Ramesh P, Kiran DR.proposed a Novel Approach for Human Identification

through Fingerprints that focussed on a person's identity recognition in realtime by mathematical analysis of the random patterns which are visible from some distance within the finger print[11].

III. TYPES OF FINGERPRINT PATTERN

The fingerprint patterns can be listed into three categories.

3.1 Arches

This is a fingerprint pattern in which the ridges run from one side to the other side without any turn. Commonly, there is no delta in an arch pattern whenever there is a delta point, no recurving ridge intervenes between core and delta points [12]. There are four types of arches as follows:

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

3.2 Loops

Patterns in which the ridges flows inwards and returns in the direction of the origin. A ridge enters in either side of the impression, re-curve and terminates in the direction of the side where ridges entered. There are four types of loops.

- Plain Loop.
- Lateral Pocket Loop.
- Central Pocket Loop.
- Twinned Loop.

3.3 Whorls

These are the fingerprint patterns in which ridges form circle around a central point. A pattern that consists of two or more delta points is known as 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

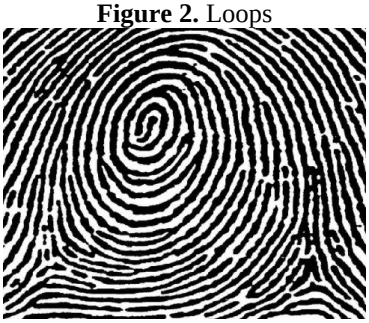

Figure 3. Whorls

IV. EXISTING METHODS

4.1Minutiae based Approach

In biometrics and forensic sciences, minutiae are used for the verification of the fingerprints. They have the prominent capabilities which can be used to compare one sample with another [9,13]. It includes ridge bifurcation or ridge finishing on a fingerprint. Detected minutia in a fingerprint pattern is identified with the help of fixed attributes such as minutia position, minutia route and sort along with bifurcation or finishing. A fingerprint is represented with the help of a set of minutia present in the fingerprint pattern [14].By evaluating trivia points present in two images, a fingerprint can be verified. Minutia is saved as the composition of attribute values together with minutia role within the fingerprint pattern [14,15,16]**.** Minutia based fingerprint recognition system is one of the popular strategies which achieves accurate results. It consists of following four steps:

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

Accurate illustration of a fingerprint pattern relies upon on accurate extraction and storing of minutia records inside the fingerprint image. The representation of the fingerprint sample should be accurate as many large-scale business systems are dependent on fingerprint recognition systems. A minutia factor is recognized as follows:

If the brightness value of a pixel is transposed, ridge endings end up bifurcational and vice-versa. The tip of the ridge or

valley is the function of the minutia. Minutia extraction techniques can be classified into the following categories as binarized fingerprint snapshots and gray scale fingerprint images [15]. Unthinned binarized images , 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 binarized fingerprint image. Ridgeline glide based totally and fuzzy based totally methods comes under grayscale fingerprint snap shots [15]. Trivia primarily based fingerprint recognition systems achieves higher accuracy. It has the following drawbacks:

- It can have corrupted or noisy images (images with artifacts)
- It cannot be used with fingerprint recognition systems. High quality fingerprint images are used.
- Minutiae based approaches are slow for real time applications.

4.2 Pattern Recognition Approach

Fingerprint includes composition of ridges and valleys referred to as styles. Patterns are used for the purpose of authentication. Pattern recognition is implementing identities of entered facts by spotting patterns it includes and relationships it maintains [16]. Pattern Recognition methods are broadly divided into following categories as: decision, theoretic and structural. Quantitative descriptors that includes vicinity, length and textures are used to describe a sample beneath selection theoretic approach.. Such system is required to locate the pleasant descriptors that could represent a pattern in a great way [16]. Pattern based fingerprint recognition system works with help of generating the data, where input is generated. The motive of doing Pre processing is to make the image smooth and free from noise. Next, functions are extracted and stored as feature vector. Whenever entered parameters are furnished, they are matched with Feature Vector database and based on the result, authentication is granted or rejected [17]

4.3 Wavelet based Approaches

Wavelet transforms are used in fingerprint patterns with the aim to provide authentication. Wavelets reduce information into distinctive frequency additives and each element is studied with a resolution matched to its scale [18,19]. In this technique, fingerprint images are decomposed using 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 [18]. 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. The wavelets have directional resolving strength of extracting texture facts LL, LH, HL and HH diagonal instructions. Also, wavelets based systems doesnot need pre processing of image or publish processing. Hence they may be fast whilst compared to trivialities based totally procedures. The other main benefit of wavelets is that it makes automated fingerprint recognition systems more accurate as it performs minimal three degree of texture decomposition. The most of the texture evaluation schemes lack because of the image is analyzed at single scale. The wavelet method is helpful in the identification of gender.

4.4 Machine Learning Based

The machine learning based methods in fingerprint recognition have great features and performing very well [16,17,18,19]. The challenges has been reduced in fingerprint recognition and results are more accurate with the advancement in deep learning .But all this is done at the cost of hardware due to computation power required in these algorithms. It will be more efficient to use the Fuzzy logic and neural network based approach. Neural network performs the fuzzy logic membership functions to identify the fingerprint [13]. The further enhancement is also suggested in [20] which follows the same issue but deal with optimising the neural network weights and biases by PSO optimisation instead of conventional LM method.

V. CHALLENGES IN FINGERPRINT RECOGNITION

The performance of any fingerprint recognition device is based on the quality of fingerprint image to a larger extent. Quality of a fingerprint image is dependent on various factors such as pores , skin conditions, sensor, poor consumer cooperation, etc. Some of these factors can be controlled whereas some changes over time. Therefore, lack of robustness is a challenge in fingerprint recognition systems [21].

Another difficulty in fingerprint recognition system is multiple sensors are used. Different sensors interpret and represent fingerprint image in a different manner [21]. The overall performance of the fingerprint recognition systems can be affected in case if sensors are changed. It can be an outstanding thought to represent fingerprint images underneath a common place exchange layout. Another way to get rid of this problem is to normalize the raw data and extracted features. These systems are prone to attacks. Unfortunately, fake entries to biometric recognition structures have proven to be successful. Matching rate (threshold cost) is an essential element in such systems. Further challenges can be matching fingerprints which can be influenced with plastic distortions. One of the major challenge can be the classification technique for an efficient search of fingerprint in a fingerprint database[21].

VI. FINGERPRINT ENHANCEMENT TECHNIQUES

It is crucial to enhance fingerprint image for its better utilization by the system. In general, fingerprint image is full of noise as human hands frequently comes in contact with different things in daily routine that makes their hands creased, grimy, moist, dry, cut, worn,etc. The main aim of image enhancement is to remove the noise from fingerprint images so that ridges against valleys can be seen. Image enhancement strategies are categorised as spatial domain techniques and frequency domain techniques.

Spatial domain techniques deals with pixel of an image. In frequency domain methods, Fourier remodel of an image is extracted. All the necessary image enhancement processes are applied on Fourier remodel of an image and then finally, inverse Fourier remodel is implemented to get the noise free image [22]. Some fingerprint enhancement strategies under spatial domain and frequency domain are as follows:

6.1 Histogram Equalization

Histogram equalization is largely used to adjust image intensity in order to enhance contrast of the whole image. A relative frequency of various grey levels available in an image is graphically represented using histogram[22]. The contrast of an image can be improved by equalizing the histogram. It is categorised as a spatial domain technique and is of great use in image enhancement [22].

6.2 Fourier Transform

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

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

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

for u = 0,1,2,…31 and v=0,1,2,3…31

Now a block is enhanced using a 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

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

6.3 Filtering Methods

To suppress both high frequencies and low frequencies in an image, filters are used. Higher frequencies within the image are filtered that makes the output image easy and limiting low frequencies enhances or detects edges in an image. The filters are used in both frequency domain and spatial domain. Various types of filters are available that are suitable for fingerprint image enhancements.

Median filtering is used to eliminate salt and pepper type noise. In this, a median value of all the pixels in a window is calculated and this value is changed with pixels across the window [22]. In the median filtering, pixel values of the window are arranged in an order and then the median value is chosen among those pixels.

High pass filtering is used to extract edges of the image. High pass filtering sharpens the brink of the image. To achieve this, a fraction of excessive bypass filtered image is added to the unique image. This is the main aim for most of the image polishing fashions. High pass filters tend to hold excessive frequency facts even as decreasing low frequency information [22,23]. The main feature of high pass filters is that it can improve the brightness of the centre pixel relative to neighbouring pixel.

Directional filtering is used for facet detection. Edge of an image can be 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 can compute first derivatives of an image [22,23].

Another technique called Laplacian filters is used to hit upon edges of an image. Laplacian filters are used to compute second derivatives whereas directional filters compute first derivatives. Second derivatives constitute the rate of change of first derivative. Hence, we can determine whether or not the adjacent pixel values are edges or non-stop progression [22,24].

6.4 Comparison between different Fingerprint Image Enhancement Techniques

Matching algorithms does not face challenge in matching exact first-rate fingerprint image. But if the image quality is not good, it's far a trouble for fingerprint matching set of rules and in this situation, fingerprint image enhancement is compulsory. In Fingerprint recognition systems fingerprint image is scanned ,then pre processing is done, then features are extracted and are stored as function vectors in the fingerprint database and matching of the input fingerprint is done with the saved fingerprint.

There are many fingerprint image enhancement strategies; few of them are working underneath spatial domain and few in frequency area. Various fingerprint enhancement techniques are compared below[25]:

Histogram Equalization works directly on the image pixels of a fingerprint but the drawback of this method is that it is discriminate and it can be lead to increase in background noise[25].

Band pass filtering makes the image noise free and true structures and ridges of fingerprint are maintained of a fingerprint but it is unable to work when the heavy noise is present in an input image[25,26].

In Binarization and thinning connectivity of the ridges is preserved and the features of a fingerprint are prevented from the distortion but sometimes it may produce empty median lines in an image of a fingerprint[25].

2D fourier transform is faster and the noise removal from fingerprint image is more effective in it. The drawback is directional selection is poor for the diagonal features[25].

VII. CONCLUSION

In this paper, a detailed review on fingerprint recognition systems has been studied and discussed with their challenges and applications. Fingerprint recognition system is 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. To achieve accurate and robust results, a good quality as well as noise free image should be used as an input. The limitation of getting an error at the time of authentication has also been addressed and finding fingerprint recognition for fingerprint obtained with label or class can be the solution to minimize this problem and make the fingerprint recognition system more accurate .

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