Latent Fingerprint Indexing and Segmentation Techniques

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Abstract*: Over the past few years, fingerprints have been considered the most sensitive and crucial identification basis for low enforcement agencies. In crime scene and forensics, recording of latent fingerprints from uneven and noisy surface is difficult task and conventional algorithm fails in most of the time. A robust orientation field estimation algorithm is the need of the time to recognize the poor quality latent. To overcome the limitations of conventional algorithm various techniques have been proposed in the last one decade. In this paper a comparative study has been done of state -of -the- art techniques with their advancements and limitations. A thorough orientation to the basics of fingerprint indexing, its classification and feature extraction has been discussed .Our proposal aims at effectively minimizing the difficulties faced to separate ridges and segmentation of latent images reducing search time and computational complexity and to identify the correct pattern from latent or partial fingerprints while optimizing the system retrieval performance.

***Index Terms*: Coherence, indexing, latent, minutiae, ridges, skeleton, , variation.**

I. INTRODUCTION

Fingerprint extraction has always been considered elementary to identify the suspects as it serves as an identification and evidence in crime related cases because of its uniqueness and invariability with respect to a person regardless of passage of time. With technological advancement there has been wide use of fingerprints tracing and identification in order to achieve maximum personal security. Fingerprints are employed to achieve security in case of cell phones, biometric door locks, attendance machines, Indian aadhar card which is amongst the largest biometrics usage around the world and one of the physiological characteristics of fingerprints are that they leave traces , i.e. once you leave your fingerprint over any object , they can be recorded later which is the main reason of recording them on crime locations in order to gather information about the criminal but the fingerprint traces are often in the latent form and fingerprint extraction from rolled and rough surfaces is a challenging task and there is every possibility of human error therefore rigorous study has been made and ample of methods has been invented for fingerprint identification using automation which minimizes errors .One of the proposed methods so far is indexing and fingerprint matching through segmentation where steps are involved from storing information of minutiae and generating skeleton structures in order to obtain a matching score. In this proposal using the support vector machine (SVM) the latent finger prints will be segregated through linear regression minutiae points and ridges. Features of latent images are further extracted using components such as gradient, ridge and image intensity. Where Gradients are studied by image edge detection technique, detecting accurate edges from the outline of the latent object through basic properties associated with an image like area, perimeter and shape (1) .Ridges are set of two variables and curves whose points are local maxima in N-1 dimensions the union of ridge sets and valley sets together form the connecting set of curves that intersect the critical points of the two dimensional image which, goes through the image intensity processing ,the process includes adjusting the brightness and contrast with the image resulting to visualization of the image much easier where the intensity values are extracted from the multiple ROI.

Since Fingerprint indexing is one of the most essential topic in the field of latent finger print matching techniques it will allow us in prompt matching of the query against vast set of enrolled finger prints called the search space without missing on explicit details.

Below is the figure and details showing variables of a fingerprint for understanding indexing in brief.

Fig,(1), Fingure indexing variables

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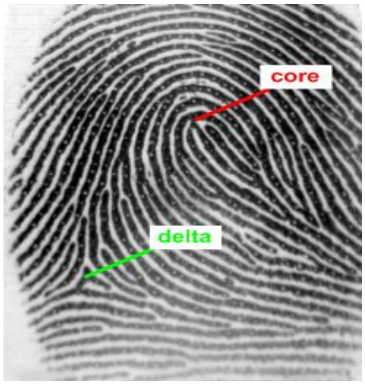

Fig,(2), Fingure indexing variables –Delta & Core

1.Ridge Bifurcation: it is can be present in prints where one ridge splits into two ridges it is found on every print irrespective of any fingerprint.

2.Pore: It gives the look of impression of holes in a ridge which are cavities and relatively very small but identifiable when enlarged properly.

3.Core :as you can see in Fig.(1) it is found in loops or whorls and usually seen where a ridge turns and runs back along itself with no ridge inside it and again it is very unlikely that the other person has one of these in the exact same position as you.

4. Delta: Mostly it is located in a whorl or loop print it is formed when a triangular shape is obtained from a ridges coming close together in different directions meeting at a point.

5.Ridge Ending :It is present in any fingerprints forming unique starting most likely anywhere in the print which ends suddenly forming the ending it gives a individuality to a fingerprint.

Apart of the finger indexing variables Finger indexing biometrics is a topic of considerable importance .One of the common form of preprocessing or extraction techniques divided into four component basically (ACE-V) Technique.ie. Analyzing, Comparison, Evaluation and Verification (1) Analyzing- It is manually marking of features such as minutiae, orientation field and ridge frequency .It is done by observation and image isolation methodology aim is to decide the availability of required ridge information from the selected fingerprint data..This step is performed manually by latent experts (ii) Then comes comparison of latent images with the exemplar images in terms of deciding and ascertaining similarity and dissimilarity between latent and exemplar prints. It refers to the process of comparing a latent image to a reference image and recording its similarities and dissimilarities. All the three levels of fingerprint namely Level 1, Level 2 and Level 3 are compared at this stage (iii) The latent examiner then determines the strength of the evidence. It refers to evaluating the fingerprints as individualization or match, exclusion or non-match and inconclusive. (iv) The 2nd latent examiner independently evaluates the latent exemplar pair to conclude and validate the previous results with first latent examiner.

II. RELATED WORK

Many researchers and scientists have achieved a higher matching score with good accuracy and enabling a Lights-out system. A semi lights-out system is in process since the current algorithms cannot result into a unique match as partial ridges can get matched with a series of people in the database hence at the final stage , an expert needs to match the latent prints with the prints of the individuals listed by the algorithms. Currently, studies are performed in order to achieve a Lights-out system so that the complete fingerprint matching system can be automated.

In this approach, we store information about the ridges, delta , pores and singular points and on the basis of these points , we match the fingerprint with the fingerprint stored in the database . Also to increase the accuracy of the working algorithms, emphasis has been given on feature extraction from the portion which could yield maximum results. The pre-processing techniques categorises basically into Equalisation of bad quality latent fingerprint image into proper sequence to convert into a clear ridge structure then segmentation that is fine separation of fingerprint from the foreground and background image which is altogether a bigger topic which will be further elaborating followed by Thinning down to useful and most useful ridge clearing and then smoothing the ridge orientation field flow across flat surface of fingerprint image and lastly gray-scale iamge converting into binary images called binarization (2).Redefining Segmentation and in detail to our topic Dividing the fingerprints into segments in order to collect information from the fingerprint is known as fingerprint segmentation. In this process , a segment of the latent print having least noise and proper ridge information is processed through various image processing algorithms and then ridge information is collected from these segments which is matched against the stored fingerprints in the database . These stored fingerprints can be either rolled or slapped fingerprints or latent fingerprints. (figure 3,4,5)

(3) Rolled Fingerprint (4)Slapped Fingerprint (5)Latent Fingerprint

Rolled Fingerprint - Fingerprints recorded from one side of the finger to other side of the finger are called as Rolled Fingerprints, These are also known as nail-to-nail prints and stores the complete fingerprint in highest quality. These are available in NIST databases and are used to match possible suspects from the latent finger print samples.

Slapped Fingerprint - Prints that store information about only primary face of a finger I.e. the prints from the front side of finger only. They do not contain any information about the edges of the fingerprint. In order to match these prints with latent fingerprints, ridges are recorded and matched with those of latent print and singularity points are recorded.

Latent Fingerprint - These are the fingerprints that are recorded form object or other surfaces. These do not contain complete information as they are not complete. These prints are not clear as they might contain noise.

For feature extraction, noise is removed and the quality of image is improved and points are recorded in order to match them with other fingerprints present in the database.
Fingerprint searches are performed in order to find the suspects from a crime scene. These searches are performed to match them with the recorded fingerprints stored in the database to get a match. There are two types of matches performed for computing a matching score.
Tenprint Search this type of search is performed on the basis of ten fingers of a person which are then searched amongst the fingerprint record database of a person whereas Latent Search is developed from the crime scene the latent print is searched against the known database of fingerprint.
Dividing these fingerprints into segments play a major role in increasing the accuracy of latent fingerprint matching and marks the development in the field of biometrics. The science of biometrics has developed a lot in these last years from manual matching of fingerprints captured from a crime scene to getting closer and closer to a Lights-out system , in order to achieve highest accuracy in fingerprint matching and shortlisting suspects as early as possible .

III. LITERATURE REVIEW ,RESULT AND DISCUSSION

The fingerprint science had been through a phase of development for a large span of time. Even now, many researchers and scholars trying hard studying and applying every approach to implementing them and checking their accuracy. **Karimi and Kuo**[3] proposed a segmentation technique known as automatic latent fingerprint segmentation technique, it measures the variability in ridge frequency and gradient in local blocks .Later in 2011, another researcher named **Short et al**.[4] proposed another technique in this technique, a latent print was cross-correlated with the similar template of ridge patterns. After this, **Choi et al.** [5] Segmented foreground from background by combination of fingerprint orientation tensor and frequency tensor information. This algorithm achieved rank 1 accuracy of 35.19% on WVU [6] database and yielded a MDR[7] and FDR[8] of 14.78% and 47.99% respectively in SD-27 database.
This technique includes extraction of features such as minutiae, ridge bifurcation, ridge wavelength map and many more. These features are classified as three levels used for feature matching .Listed levels includes features for

- Macro details such as singular points pattern type and ridge flow
- Ridge skeleton, ridge bifurcation, endings and ridge contours
- Sweat pores, dots and incipient ridges which are robustly extracted and requires high resolution images.

According to a research paper named “A fingerprint segmentation technique based on Morphological processing” Segmentation is an important pre-processing step in AFIS[9]. This helps in discarding the useless minutiae which could not provide any information for matching or the portion of fingerprint which is not clear.

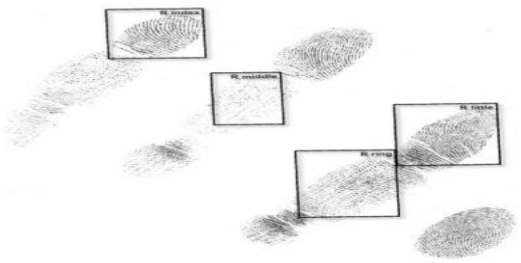

Fig.[6]:The segments recorded by using NIST Fingerprint Segmentation Algorithm

Moreover fingerprint features except minutiae and singularity points are called as extended features. Studies have been performed till now in the field of fingerprint segmentation and matching .**Zhang et al.**[9] Proposed a variation of TV-L2 which was called ADTV model. This model is used where the textures are decomposed with orientation pattern which in turn forms a defined structure in foreground ridge regions. After this, **Cao et a**l.[10] Used another method to learn a thin representation of ridge like patterns. This method involves a combination of coarse and fine structure ridge dictionary.
Feng et. al.[11] Contributions- According to him , the extracted features have variation in situation of noise since they are based on structural relations between the ridges . Also, the number of indexes which could be found by giving three minutiae is much greater than any triplet based algorithm.
Liang et. al.[12] Contributions- He defines a very robust feature that classifies burification of the ridges in ten cases . The disadvantage in this algorithm is that the amount of burification types is not uniformly distributed. **Moses**[13] suggested a method in which he proposed that latent fingerprint can be matched by AFIS. After Moses, **A.K. Jain**[14] et al .proposed an algorithm that matches latent fingerprint with full fingerprint images. In this approach fingerprints were manually segmented, minutiae and ridge flow were recorded. **Yoon et al**.[15] proposed another algorithm to increase the matching accuracy and is known as latent fingerprint enhancement algorithm.
In one of the work performed by **A.K. Jain and Feng**[16] , they worked on features in order to match fingerprints by using minutiae ,ridge flow map , ridge wavelength map, ridge quality, singularity and skeleton structures to match latent fingerprints with rolled fingerprints.
Research have been performed till date in latent fingerprint indexing. These studies include algorithm developed on the basis of minutiae, ridges and many more .The indexes are calculated using features extracted from the fingerprint. The features of impression having minimal variations in situation of noise and distortions are best suited for acceptable performance . Correct identification is ensured in this case discarding the quality of image. This results in the better application of algorithms. Below are few approaches.
Baseline Matching Algorithm:-
There is another algorithm for latent fingerprint matching. It comprises of following stages-
Local Minutiae Matching- In this matching, similarity of each minutiae of latent fingerprint and rolled fingerprint is computed. Global Minutiae Matching- In this matching, all the most similar minutiae pairs found in local minutiae matching are used. These are called as initial minutiae and

a ravenous matching algorithm is used to compute a matching score.

Matching Score Computation- Matching score for each similar pair is computed and the maximum score is considered as the matching score between latent and rolled prints

Further there are so many approaches for fingerprint indexing based on the minutiae involved . These approaches include.

- Non-Minutiae based approaches- These algorithm is independent of minutiae. This approach includes representation of OFs based on a set of PCMs for fingerprint indexing
- Minutia single based approaches- These algorithms are based on minutiae singles. There is an indexing algorithm where features extracted from minutiae singles
- Minutiae double based approaches- These algorithm are based on features resulted from minutiae pairs. Their feature vectors are not similar to any geometric transformation of fingerprint.
- Minutiae triple based approaches- These algorithms are based on minutia triplets and triangles formed by them. The triangles were used as an indicator in their indexing approach.
- Minutiae quadruplet based approaches- These algorithms are based on Minutiae Quadruplets. It involves three types of irregular quadruplets namely convex,concave and reflex.
- Minutia K-plet based approaches-These algorithms approaches are extracted from the nearest neighbour of each minutiae and are an extended version of nearest Neighbour local based structure.
- Minutia Cylinder Code(MCC) based approaches- These algorithms combines the advantage of both NN and fixed radius local structures , and encodes spatial and directional relationships between central minutia and its neighbourhood by showcasing its nearest minutia to a TRI- dimensional space in shape of cylinder .

Other affecting aspects being the number of indexes which are generated and their ability to capture the characteristics for best fingerprint definition .Few methods are mentioned below:-

Adaptive Total Variation Method- In this method , measuring is done over features such as coherence , mean and variance. While processing , we select different values of lambda in different fingerprint image regions . It provides satisfactory results but it does not perform accurately and is used in fingerprint segmentation.

Directional Total Variation Method- In this method , we use variance feature and a spatially varying orientation vector . During processing , it is required to align the orientation vector well aligned with local fingerprint ridge orientation. It was better than the Adaptive method and was used in decomposition of images with oriented textures.

Method based on Ridge Orientation combination and Frequency Features- In this method, we measure ridge frequency or ridge density and mean value. In this method , Orientation and frequency features are separately determined for each print and their intersection was taken . Its limitation was the unavailability of robust confidence measure for segmentation output . It produces results in accordance to visual inspection and is applied in fingerprint segmentation.

Combined Method- This method is the combination of Orientation Field information and Statistical characteristics of Gray. In this method , mean gray value and variance are measured . This method could not yield good results in case of an image which is either super wet or super dry . On the other hand, it improves accuracy as well as reduces processing time. Ridge Template Correlation- This method involves calculation of Image mean and variance. In this method , there is a lengthy algorithm which is required to be followed orderly for achieving effective results . The problem with this method is that sometimes, it labels background as foreground incorrectly in case of large fingerprint or missed minutiae. It advantageously reduces the average detected fingerprint area Three Pixels Feature- These three pixel feature comprises of the coherence , the mean and the variance and the whole result depends on the calculation of these three pixels features. The necessarily required step in this algorithm is post processing of segmented fingerprint image but a small percentage of pixels is sometimes misclassified. Its advantage is that it results in accurate high resolution segmentation results.

IV. CONCLUSION

1. Approach of Fingerprint Matching is much improved and accurate and brought science a more closer to achieve a Lights-out system .
2. For covering all the minutiae , many approaches were studied on the basis of number of minutiae involved as these features result in indexing and better indexing means better matching regardless of the quality of image of fingerprint .
3. Fingerprint scanning and matching plays an important role in forensics and criminology. To achieve better results , a pre-processing step was introduced which was known as segmentation in which the whole fingerprint was divided into segments and then matching was performed which result in increased accuracy and reduces matching time .
4. Minutiae approach yields better results and to achieve a Lights-out system it required to develop more approaches in order to achieve an error free system. The further works must be carried out on segmentation and indexing as these would help to improve the accuracy of matching algorithms. More feature extractors and image enhancers are required in order to get a sure hit of a fingerprint .
5. A new approach is required to match latent fingerprints to rolled and slapped fingerprints to improve accuracy and matching score

V. LIMITATIONS

There are several difficulties that occur while matching Latent Fingerprints. This are-

1. Low quality of latent print in which ridge information is not clear.
2. Smaller finger area captured during scan in latent print as compared to the finger area registered in rolled fingerprint database.
3. Large non-linear distortions due to pressure variations.
4. While searching for fingerprints to obtain a matching

pair, there could be errors involved that may lead to problems. These errors are incorrect and improper Individualization.

5. When the mated fingerprint of the latent print is present in the selected database but the latent examiner fails to identify it while reviewing. It is also known as False Reject.
6. When the latent print is wrongly matched to a fingerprint of another subject by latent examiner. It is also known as False Accept.

VI. FUTURE WORK

We would be searching for more better approaches in Fingerprint Indexing and try to achieve a Lights-out system with better accuracy and least matching time . We would also try to develop new approaches by indexing method using algorithms and further segregating minutiae based latent images by segmentation technique.

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