# Overlapped Fingerprint Separation using Graph based Model

Sonali Sen
*Department of Computer Science*
*St. Xavier's College (Autonomous)*
Kolkata, India
sonalisen@sxccal.edu

Manjistha Paul
*Department of Computer Science*
*St. Xavier's College (Autonomous)*
Kolkata, India
manjisthapaul999@gmail.com

Rajarshi SinhaRoy
*Department of Computer Science*
*St. Xavier's College (Autonomous)*
Kolkata, India
rajarshi921@gmail.com

Chayan Kumar Sengupta
*Department of Computer Science*
*St. Xavier's College (Autonomous)*
Kolkata, India
swapnomoy199916@gmail.com

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***Abstract*—For over a century, fingerprint analysis has been used to solve crimes, identify and track offenders. A common problem during the identification of a fingerprint is overlapped portion identification. This work aims to separate an overlapped fingerprint first and then identify the two separated fingerprints. In this approach, the parameters from a fingerprint are extracted and then represents with a graph based model using an adjacency matrix. Neighbour-finding algorithm has been applied to the matrix to track the ridge bifurcations. The proposed work aims to suggest the matrix representation of a sample with overlapping varies by a deviation factor from a non-overlapping segment. As a result, it can be made a concerted effort to sort out the overlapped fingerprints before relying on fingerprint matching in any significant way. The proposed graph-based approach successfully separated the overlapped portion and then match both the fingerprints.**

***Index Terms*—fingerprint matching, Minutiae points, overlapped fingerprints, fingerprint segregation, deviation factor**

## I. Introduction

Fingerprinting has a lengthy history, dating back before it was used in criminal cases. According to historians, Babylonians recorded economic transactions by pressing their fingers into wet clay. The Chinese copied this strategy but preserved its benefit as a unique identifier, using ink on paper to perform commercial transactions and identify their progeny.

Fingerprint matchers, work based on extracting and comparing ridge characteristic spots (minutiae) of a fingerprint. As a result, for successful matching, consistent ridge extraction is a critical issue. Existing ridge extraction algorithms perform as expected when ridge structures are well defined and there is little noise in the fingerprint image. However, there are a variety of difficult scenarios, including overlapping fingerprints, where state-of-the-art matchers fail miserably. Latent fingerprints taken from crime scenes frequently have overlapped pictures. The surface of fingerprint sensors includes the residue of previous users' fingerprints where overlapping can occur in live-scan fingerprint images.



The terminologies related to fingerprint which help to identify the minutiae points are enlisted below:

- Loop- The loop pattern consists of one or more free recurving ridges and one delta. Ulnar loops are the loops flowing from the little finger side, whereas radial loops flow in from the thumb side.
- Arch- The Arch is made up of ridges lying one above the other in a general arching formation.
- Whorl- The whorl pattern consists of one or more free recurving ridges and two points of delta. When the line of the fingerprint disc is placed on the two points of delta, it will bisect at least one of the ridges belonging to the core group.

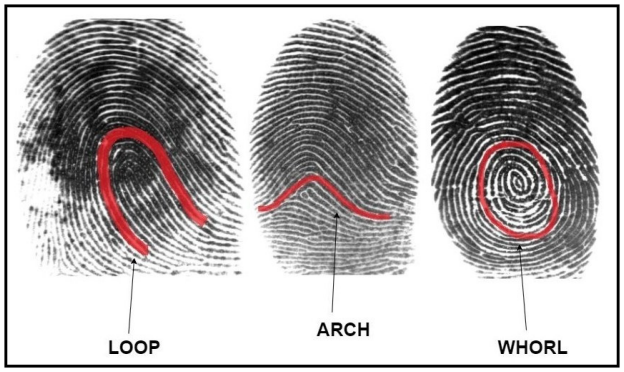


Fig. 1. An Illustration of (a) loop [28], (b) arch [28] , (c) whorl [28] in fingerprint

The papillary ridges on the ends of the fingers and thumbs leave a fingerprint impression. Because the ridge arrangement on each human finger is unique and does not change with growth or age, fingerprints provide an accurate form of personal identification.

The ridges appear as dark lines in a fingerprint image, whereas the valleys appear as bright areas between the ridges. The points where a ridge becomes discontinuous are known

as minutiae points. A ridge can either come to an end, known as termination, or split into two ridges, known as bifurcation.

Fig. 2. An Illustration of Ridge Endings and Illustration of Bifurcation

Fingerprint recognition is a biometric automated identification method to compare one fingerprint with another to determine if the impressions are from the same finger or palm. Fingerprint recognition consists of two subparts: one part is fingerprint verification, and the other part is fingerprint identification shown as in Fig-3.

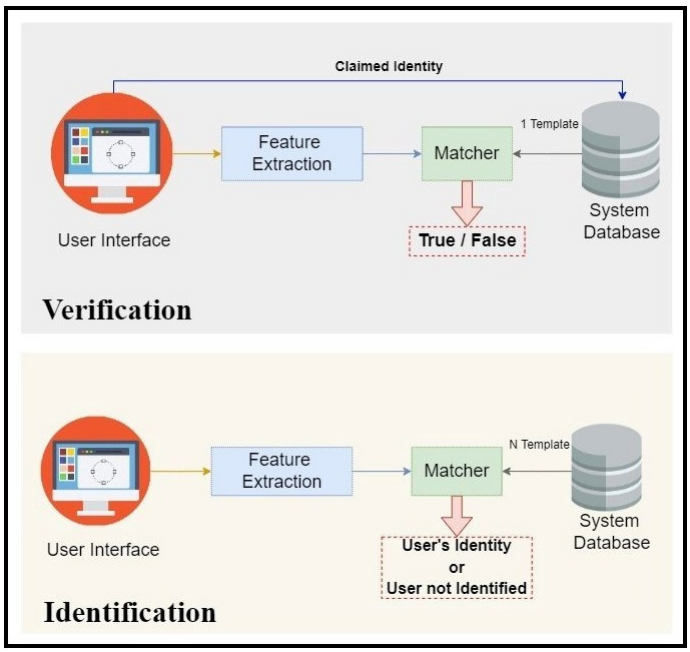


Fig. 3. An illustration of verification and identification process

After the fingerprint sample has been considered, the target is to identify if there is any overlapped portion. The deviation factor of an overlapped segment from a non overlapped one is considered. After successful identification, the separated components are sent for further fingerprint identification where other samples are matched with the input sample from the database (1 : N) matching. The proposed work is detailed in Section 3. Sections 4 and 5 provide the findings and conclusions. Finally, our study includes a list of references.

## II. LITERATURE SURVEY

Sonali Sen et al., [1] proposed work demonstrates the use of graph theory in the field of fingerprint identification, in which a fingerprint is cast to a weighted complete graph, and the weight matrix of this graph is used to describe the regions in the image, and then the image is checked for biometric authentication without taking Henry's classes into account. A fingerprint is cast to a weighted complete graph, and the weight matrix of this graph is used to describe the regions in the image, and then the image is checked for biometric authentication. The approach was evaluated on a database of Fingerprint Verification Competition (FVC) results and found to be more efficient than image processing. F. Chen et al., [2] proposed a unique approach for separating overlapped fingerprints into components or individual fingerprints. Researchers retrieve individual orientation patterns by utilising the initial orientation pattern discovered by localised Fourier analysis as the starting point for a relaxation expression. Applying Gabor filters tailored towards the part orientation fields to the fingerprint image containing two distinct fingerprints overlap. D.K. Isenor et al., [3] proposed a work that introduces a new fingerprint encoding and matching technique by using the concept of interconnections between the fingerprint ridges topologically. Ravi. J et al., [4] developed a method where minutia points are matched using the Minutia Score Matching method of fingerprint recognition. If the matching score is 1, the images are matched; if it is 0, they are mismatched. Anush Sankaran et al., [5] proposed research into automated latent fingerprint matching technology is still in its early phases. Identifying latent fingerprint-specific features could be a suitable avenue to pursue in the future. They're also working on increasing the matching performance, which is the goal of an automated matching system. Heeseung Choi et al., [6] suggested a unique matching strategy employing a breadth-first search to incrementally find the matched minutiae pairs using the proposed ridge features and conventional minutiae features. The authors conclude that the proposed ridge feature provides additional information for fingerprint matching with a small increase in template size and can be used in conjunction with existing minutiae features to improve the accuracy and robustness of fingerprint recognition systems. Mouad.M.H.Ali et al., [7] presented a new minutiae-extracting algorithm as well as the minutiae matching technique utilising the Euclidean distance scale to estimate the similarity measure of fingerprints, concentrating on ridge termination and bifurcation. Manvjeet Kaur et al., [8] suggested a model that can precisely thin the fingerprint, identify more bifurcation, and eliminate false minutiae. This allows for the improvement and enhancement of fingerprint images. N.Surya et al., [9] suggested a fake minutiae removal approach with the concept of fuzzy if-then rules as well as fuzzy reasoning. Ravi. J et al., [10] analysed the various approaches using fuzzy logic and neural networks, and came up with a reliable solution for matching fingerprints. Gian Luca Marcialis et al., [14] suggested a recommendation to comprehend the graphing process for fingerprint representation and matching. Hence, Further research is necessary since graph-based methods for classifying fingerprints may have certain advantages. This is especially true when integrated with quantitative methodology.

## III. PROPOSED APPROACH

The proposed approach has two different parts. First the overlapped fingerprint is separated and then the identification is done. The block diagram of the proposed method is shown in figure 2.

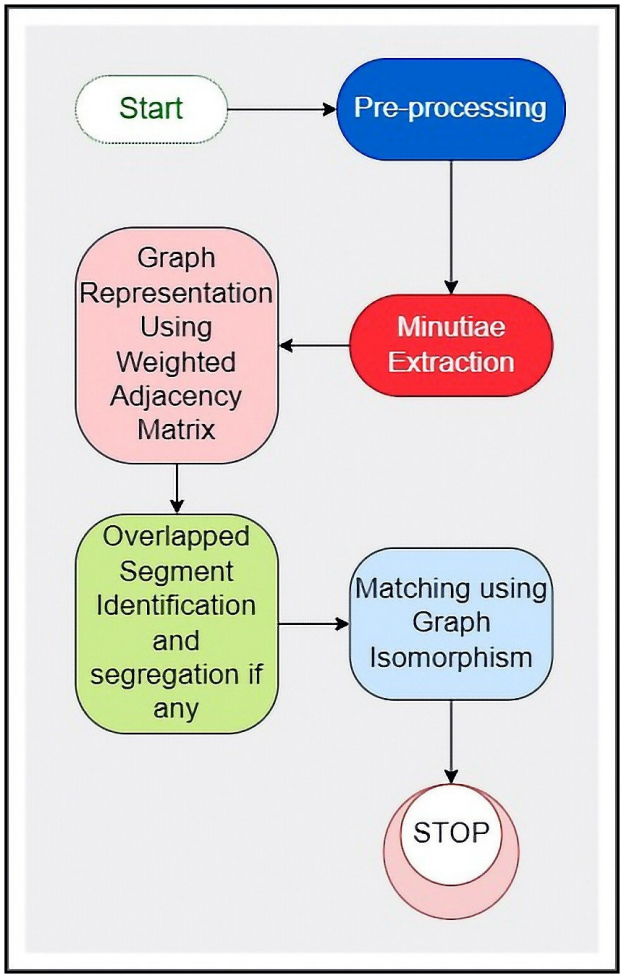


Fig. 4. An illustration of a Block diagram of the proposed method

The steps of the proposed method are explained as follows:

### A. Preprocessing

In pre-processing all the unnecessary information is removed from the fingerprint image, like distortion, reflection, etc. Different grey scale and backdrop exist in the fingerprint collection, which can affect the quality of fingerprint photographs. So, Pre-processing is being used to improve the visibility of the ridge structure. The pre-processing procedure consists of three main phases: fingerprint enhancing, binarization, and thinning. Normalization, Segmentation, and Orientation are the phases of fingerprint enhancement. After then, the extraction of Minutiae is Started.

*1) Fingerprint enhancement:* Fingerprint enhancement consists of three phases:

- Normalization: Normalization is a pixel-by-pixel process and for that Overall clarity of both the ridge & valley formations is unaffected. Normalization's major goal is to eliminate variances in gray-levels along ridges & valleys, making subsequent processing easier.
- Segmentation: The goal of segmentation is just to decrease the time and effort required for fingerprint enhancement by focusing solely on the front regions and ignoring the back regions.
- Orientation: The orientation image is an inherent property of fingerprint images that provides unchanging positions for ridges & valleys in a given area.

*2) Binarization:* The process of transforming a gray scale image into a binary image is known as binarization. A binary image would be one with only two levels: 0 for the ridges, which are denoted as black, & 1 for valleys, denoted as white. We use the threshold approach to binarize a picture, where a value is set and pixels below that value can be denoted as white, while pixels above that value are denoted as black.

*3) Thinning:* Thinning is just a process in which the front pixels are gradually reduced till they are only one pixel wide. Thinning can be applicable for binary images, and also the output is indeed a binary image. Before the minutiae extraction, the final image-enhancing step is thinning. The thinning is repeated until all of the boundaries are just one pixel wide. When a thinning technique is used for a fingerprint image, the connection of both the ridges & the bifurcation are preserved, which means the fingerprint features are not deformed.

### B. Minutiae Extraction Graph Representation Using Weighted Adjacency Matrix

The minutiae points of a fingerprint sample are considered, mainly focusing on ridges. Unique patterns of ridges are considered and the neighbouring relationship they share with each other. The number of pixels that establishes an edge is taken as a proportion of the length of that edge.

### C. Overlapped Fingerprint Segregation

The weighted adjacency matrix has already been computed. A cluster or sub matrix for the overlapping data has been considered. A portion of the fingerprint may be discovered while traversing all of the cells of the adjacency matrix. To separate the overlapping segment from the non-overlapped region, a recursive technique is used, with the base condition being to keep running the algorithm until the deviation factor is near to zero. The pseudo-code to determine the sub-matrix where the cluster probably has been found is given below:

**Algorithm 1:** Algorithm for Overlapped Fingerprint Segregation

**Input:** $O_{Mat}$; Weighted adjacency matrix corresponding to the overlapped fingerprint.

**Output:** $W_{Mat_1}, W_{Mat_2}$; Weighted adjacency matrix corresponding to the fingerprint of individual 1 & 2.

*Initialisation* :

$W_{Mat_1} \Rightarrow 0, W_{Mat_2} \Rightarrow 0$

1: $m$ = orderCalculation()

2: $c$ = clusterCalculation()

$W_{Mat}$ = weightedAdjacencyMatrix($m$)
*LOOP Process*
**while** $c < m + 1$ **do**
  $W_{Sum}$ = calculateWeightedSum($W_{Mat}$, $C_{Mat}$)
  $MAX_{Avg}$ = calculateWeightedAvrg($W_{Mat}$, $C_{Mat}$)
  $MAX_{Avg}$ = maximumFind($W_{Sum}$, $MAX_{Avg}$)
**end while**
*LOOP Process*
**while** $c < m + 1$ **do**
  $W_{Sum}$ = calculateWeightedSum($O_{Mat}$, $C_{Mat}$)
  $MAX_{Avg}$ = calculateWeightedAvrg($O_{Mat}$, $C_{Mat}$)
**end while**
**if** $W_{Avg} > MAX_{Avg}$ **then**
  $W_{Mat_1}, W_{Mat_2}$ = clusterFinding($O_{Mat}$)
**end if**
**return** $W_{Mat_1}$, $W_{Mat_2}$

### D. Matching using Graph Isomorphism

The concept of isomorphism in graph has helped identify the fingerprint sample with suspected ones. The sub-graph isomorphism task is a computer challenge that requires detecting whether graph G has one sub-graph from two graphs G and H that appears to be isomorphic to H. Since it is an expansion of both the maximal clique problem and the problem of identifying whether a graph contains a Hamiltonian cycle, sub-graph isomorphism is NP-complete.

## IV. RESULT AND DISCUSSION

In our Proposed Work we used the Tsinghua Simulated Overlapped Fingerprint Database where the fingerprints are based on the FVC2002 datasets. This huge dataset of FVC that has been rotated, scaled, shifted, and cropped in various ways for the aim of determining correctness. We used MATLAB2021b for our work. In our proposed work it removes the noise and make the image more efficient using pre-processing.

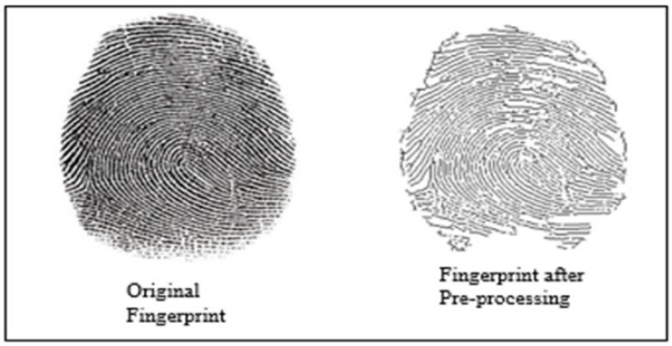


Fig. 5. An Illustration of Preprocessing on a fingerprint image.

Then the segregation of the fingerprints done by our proposed method.

In fig.6 our algorithm finds the total region and the segregated part and the it used the deviation factor to segregated the overlapped part and finally it gives the segregated fingerprint. Now this fingerprint is again used for identification.

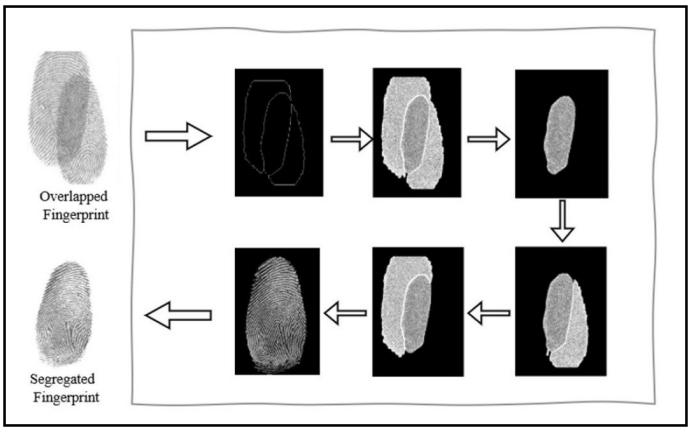


Fig. 6. Immediate Segregation of Overlapped Fingerprint using our proposed method.

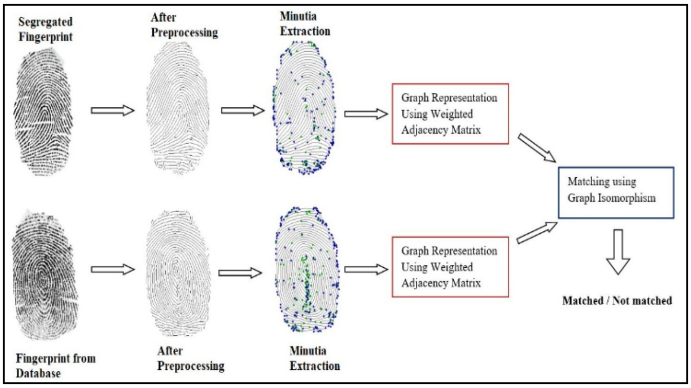


Fig. 7. After Segregation of Overlapped Fingerprint Identification is done by using graph Isomorphism.

In fig.7 the segregated fingerprint is used for minutiae extraction and then the weightage matrix is generated. This Matrix is used for the representation of the graph. The fingerprints stored in the database are the converted into graph same as discussed above. After that, the matching is done by Graph isomorphism to find out if the fingerprints are matched or not.

Table 1 summarises the findings of the Overlapped fingerprint Segregation algorithm's and the fingerprint identification algorithm's performance.

TABLE I
PERFORMANCE ANALYSIS OF OUR PROPOSED ALGORITHM

| Various Transformed Factor | Matching(%) |
|---|---|
| Two identical fingerprint overlapped | 100 |
| Two non-identical fingerprint overlapped | 97.6 |
| Two Fragment overlapped fingerprint | 98 |

## V. CONCLUSION

The overlapped fingerprint separation and the matching challenge can be reasonably accurately solved using the

method proposed in the paper. The advantages of this algorithm include its independence from tilting, its ability to securely distribute a portion online, and its ease of data storage. If a fragmented part is provided as input, our method can still analyse it, segregate those, and find matches. The conclusion is that an attempt has thus been made to both identify a fingerprint sample as well as handle overlapped fingerprint samples and segregate them. The scope for improvisation lies here if certain discrepancies like more accuracy in partial identification can be handled and the database size could be increased.

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