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# Fingerprint Reconstruction using Algorithms

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**Abstract**

Fingerprints are the crucial evidence in the field of forensic science for personal identification. It is governed by the Locard's principle of exchange. When comparing fingerprints with the Automated Fingerprint Identification System (AFIS), fingerprint identification is the most effective method for reducing suspicions about the identity of the fingerprints. From the scene of crime, investigators collect three types of prints i.e., patent fingerprint, latent fingerprint which is also known as partial fingerprints and plastic fingerprint. It is the challenge for fingerprint expert to analyze those partial fingerprints. For making the fingerprints experts work easy and effective there are various algorithms techniques developed which mostly based on the second and third level characteristics. Through these algorithmic techniques, the fingerprint image is improved by making a faithful replica of the original and then matching it with the original. This helps fingerprints experts and investigators to solve many complicated cases with accurate results.

**Keywords:** Latent fingerprints; Algorithms; Reconstruction; Fingerprint; Forensic science

## Introduction

The Oxford English dictionary lists one of the first uses of the phrase "Forensic Science" to describe "a mixed science" [1]. Forensics is the forensic study of how people, places and things are connected to criminal activity; these scientific disciplines are important for criminal and civil investigation and adjudication. The word "forensic" is derived from the Latin "forum" for "public" [2]. Forensic science mention to the implementation of natural, physical, and social sciences to matters of the law [3]. Often referred to as forensic science, forensic scientists answer legal questions through their reports and testimony. The most important concern for the forensic investigator is to identify the perpetrator and to intercept them for further act of violence and for doing this, requirement of expertise from different backgrounds is needed. Chemists, psychologists, anthropologists, computer science technicians, physicists etc. are asked to put their knowledge in forensic science field to solve criminal cases and give justice. The precise examination, collection and preservation of evidence which are found on the scene of crime are very important for fact-finding and for initiating error-free estimation and evidence elucidation irrespective the type of evidence like blood patterns, cadaver, notes, record files, disk drives and clinical information data. Collection of evidence should be done in a way that its probity will not alternate and for this the official personnel must sustain the chain of custody from the crime scene to the laboratory. A chain of custody is a process in which the officials preserve evidence all over the period of a case. Genuine crime scene examination needs additional expertise; it commands logical and innovative thinking and the veracious implementation of science and the various technical methods. Defining ethics in the forensic science field must be paramount. Some of the ethical issues listed are general for all the subfields but some of them are specific. To ensure high levels of reliability and credibility, forensic scientists must address these ethical issues. Forensic science combines the ethics of science with law so that science can be used to settle legal disputes. In the field of forensic science, the term personal ethics or morals refers to concerns experienced by forensic scientists which are not derived from professional or scientific roles; rather, these concerns relate to their personal ethics (morals) or religious beliefs. On the contrary, the professional ethics refer to the codes or guidelines that regulate the professional and scientific conduct which are more fundamental compared to personal ethics or morals [4]. Some ethics related to forensic science are listed: Professional credentials, Laboratory analytical procedures, privately employed forensic scientists, publicly employed forensic scientists [5].

Forensic science helps in to discover the presence and absence of a link between a crime, criminal, victim, weapon which is involved in the crime and the time and location. Forensic science has two peculiarities i.e., multi-professional and multi-dis-

ciplinary. Forensic science field is based on six laws or principles i.e., Law of Individuality, Principle of Exchange, Law of Progressive Change, Principle of Comparison, Principle of Analysis, Law of Probability. Among all the branches of forensic science the most important, reliable, and authentic branch is fingerprints. Fingerprints have been used for about the past hundred years and are known as the oldest sign for identification of an individual or the evidence categories in forensic science. In the 20th century, fingerprints were meticulously accepted and then used as a genuine and valid sign of identity by law administration. The fingerprints comprise composite dark segments which include light and dark areas are known as hills or ridges and valleys or furrows respectively. Due to the uniqueness of fingerprints, they are helpful in the process of identification from which we can locate, recognize, and eliminate suspects in criminal cases. The fingerprints are the friction ridges found on the skin of the fingers and is considered as one of the most fragile and versatile evidence. Friction ridges are the ridges from which the prints obtained.

Basically, fingerprints ridges start forming in the eight's week of gestation period when the fetus is in the womb and are fully formed at about 17-25 weeks of gestation. Every ridge has a distinct row of pores that serve as the entry points for sweat gland ducts. Sweat is discharged and deposited on the skin's surface through these pores, and when the skin comes into touch with another surface, perspiration and oils are conveyed onto the surface, forming fingerprint impressions. Science of fingerprint is based on the three principles i.e., a fingerprint is an individual attributes, a fingerprint remains unchanged during an individual's lifetime and Fingerprints possess general ridge patterns that enable them to be categorized comprehensively. Fingerprint identification plays an indispensable part in circumstances where an individual entail to be identified or verified with excessive confidentiality. Fingerprints impressions holds characteristics which are generally the amalgamation of the ridges and the valleys in the impression. Fingerprint verification has been dependent upon the characteristics which are fractionated into three dissimilar levels. Different varieties of details are disclosed from these three levels details within the print.

i. **First level details**: First level details include overall flow of the friction ridges, types of patterns and location of core and delta. This also includes a basic direction of flow for each print to be examined. Creases, scars, and other deformity in first level details are studied by dealing with directions and location of the features.

ii. **Second level details**: It includes the types and relatives' position of the minutiae within the whole pattern. It includes the beginning location of ridge, the ridge path, and the point where the ridge flow stops. In the case of second level details tracing of actual path occurs. All these details are more specific to the position when a ridge stops or bifurcate or converge or diverge.

iii. **Third level details**: It mentions the inherent or congenital ridge formations which involve the edge shapes, sizes, pore shape and relative pore locations. The third level details are unique in sequencing. The condition for this level is without first and second level, third level does not exist. It helps to examine the pore position and the morphology of the ridge.

The fingerprint patterns are classified by the Francis Galton namely, Whorl, Loop and Arch. Whorl constitute about 24-26%, loop constitutes the most i.e., 60-65% and arch constitutes the least i.e. 5-6% of all the fingerprint impressions.

## Classification of Fingerprints Come Across at Scene of Crime

The fingerprints come across at the scene of crime are the proof prints or the chance impressions of the friction skin which are either completely visible or are the form of some indentation. Usually, the prints present at most of the crime scenes are generally distorted in nature and lacks clarity and hence are called partial prints. There are different types of prints like: Patent prints which are form when a visible material such as blood, dirt, ink, oil, or other substances are deposited on the surface by the finger, Latent prints are those impressions left by bodily perspiration or oils being transferred from finger ridges to the surface of an object that is not visible to the naked eye, Plastic prints are those impressions which are found on any plastic material. These prints are also known as indentation prints and display the definite three-dimensional characteristics of the prints and hence need not require enhancement for their visual identification, there are other type of fingerprints too i.e., blurred fingerprints, superimposed fingerprints which comes under patent prints. Patent and plastic prints are easily examined by the fingerprint expert but in case of latent prints the expert first must developed prints from the crime scene and then do the analysis. There are different methods present by which latent fingerprints developed.

### Physical methods for development

Physical method of fingerprint development includes powder method in which different powders has been used on the non-porous surfaces. The type of powder used is dependent on the background surface. Grey and black powder, magnetic powder and fluorescent powders are the most frequently used powders for the development process.

### Chemical methods for development

There are various chemical methods present for the development. All these methods are dependent on the chemical reaction that occurs between the specific chemical and the specific components of the latent print like amino acids, inorganic salts etc. Iodine fuming method, ninhydrin method, silver nitrate reagent method, superglue fuming method, small particle reagent method, DFO method etc. are some of the most used chemical methods for the development process.


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In some cases, ridges of fingerprint impressions are lost or broken so in that scenario an investigator have to reconstruct it for the generation of orientation field and ridge patterns for the better development and analysis of fingerprints. Nowadays, it is feasible to rebuild a fingerprints impression image from the sample, then it can be compared with the original fingerprint image with high level of fidelity. Fingerprint comparison systems use four types of schematic representation methods namely gray-scale, segment and skeletal structure and small image. There are many algorithms technique available for this purpose-

a. Convolutional Auto Encoders Neural Network

b. Amplitude Modulated and Frequency Modulated

c. Type 1 Attack and Type 2 Attack

d. DORIC (Differentiation of the Orientation Values Along a Circle)

e. Orientation Field Modelling

f. Sparse Auto Encoder Algorithm

## Discussion

Fingerprint impressions is a form of biometrics, a science which can be used for the personal identification. There are many measures which can be used for the personal identification despite that fingerprinting is the most important technique and security measure for the authentication of human over the globe because of its peculiarities and individual characteristics. Minutiae are the features and the peculiar points which are used for the identification, verification, and reconstruction of a fingerprint image. For the identification purpose the investigator first must extract it from the crime scene as they are present in the hidden form, and this is the biggest challenge. To make the work simplistic and dynamic algorithms techniques developed. Various algorithm techniques have been used to strengthen the quality of the image by making a real-like image and then collate it against the original image. This helps investigator to solve many complicated cases with accurate results [6-9].

### Convolutional auto encoder neural network

By knowing the success of the convolutional auto encoders for image processing work, convolutional auto encoder neural network designed which is capable of reconstructing high quality fingerprint images from hidden prints. The neural network is instructed on a fabricated dataset which consists of partial and blurry fingerprint impressions having background noise. The output came from the network is then collated with the ground control fingerprint image. The grounding set is produced by using the open-source execution of Singe fingerprint generator. Firstly, the gradient examination of the fingerprint image ridge pattern is performed as the calculation of the image gradient can be accomplished using the convolutional operator. Ridge pattern orientation can be explained through moments of the image by using the computed image gradients. In contemplation of reinforcement the similarity in the middle of the rebuild image and the related ground-controlled figure, compute the reliability orientation field. The output of the encoder is straight sustained as an input to the decoding part. The decoder reprints the architecture of the encoder by performing the changes. Each convolutional layer is restored with the deconvolutional layer. To produce the primal grey scale image again convolutional layer issued with a sigmoid activation function is implemented at the ending of the decoder. This is the most extensively used technique for denoising and enhancing the image still have some flaws like: Many false finer points does not involve in the primal minutiae template are produced in the rebuilt image. Sometimes this technique produced only partial reconstruction of fingerprint image. Weak samples may not contain any relevant data for the process of reconstruction.

### Amplitude modulated and frequency modulated

In this way a continuous section from the ridge pattern with the same flow of ridge to the actual fingerprint. This process is completely natural and will form a continuous phase without any blocking effect. There is no spiral subsist in the continuous reconstruction phase that leaves a few segments of lines easily visible. After combining a continuous phase with a wind turbine tested from the minutiae, the process of image enhancement process is encouraged to minimize the artistic elements found in those line segments. Finally, a visual-like image printer was reconstructed in the report in an abstract plot tested from the refined phase image. The reconstructed image of fingerprints does not have obvious artifacts like blocking effects and many false points. In the AM-FM model, the fingerprint model is represented as a hologram. The phase image in this model can rot between two parts namely the continuous phase and the wind phase. For each website specialist download 800 minutiae templates, which contain only the positions and directions of minutiae points. In addition to having good points this process has some flaws such as a reconstructed fingerprint image that may have a small number of important minutiae points throughout the point of the point.

### Type 1 attack and type 2 attack

It is a significantly assessing technique. When the reconstructed fingerprint image is matched against the corresponding primal fingerprint image, it will be sanctioned as Type 1 attack. While the image is match against dissimilar impressions of primal fingerprints by using economical fingerprint SDK, Neurotechnology Veri Finger, it will be sanctioned as Type 2 attack. Type 1 attack has lofty prospects of misleading the fingerprint identification system in twain recognition and authentication experiments. A type 2 (False Acceptance) attack of 0% was detected in a validation test administered in FVC2002 DB1, and a 99.70% recognition level was detected in a diagnostic test conducted on the NIST SD4 website. Game scores obtained from attacks of type 1 or 2 are real game scores.


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### DORIC (Differentiation of the orientation values along a circle)

It is the expanded form of a Poincare Index. DORIC feature is used for singular point authentication to extricate simulated discernments and impart more neutral information. It is successful because it hinged on the analysis of core and delta relation. Excellent points were selected to minimize the difference between a prominent standing field and a model-based stand-up field using unique points. The Poincare 'Index-based strategy can find almost every true point in unity when the Index is calculated across all sub-regional genes, but this also leads to many inaccuracies. If a larger region is taken, the points of truth in unity will be easier to identify. Sequent for special detection while maintaining a good diagnostic standard, a novel feature is proposed from the Poincare ' Index, which can provide highly biased features and be used to verify the reliability of all diagnoses after using the Poincare 'Index algorithm. In cases where there are grooves, marks, smears or printed prints on fingerprints, the Poincare 'Index process will automatically result in many false points in unity. The DORIC feature changes curves slightly by changing the sound in one place which creates the difference between true and false points in unity.

### Orientation field modelling

It plays a paramount part in fingerprint augmentation, quality estimation, characteristics recognition and characteristics matching. This algorithm uses symmetric filter which depend upon weight assessment, local standardization, and weighted orientation field modeling. Based on dependability in ridge-valley flow weights are assigned. The main objective is to conserve the genuine orientation field in the regions which accommodate steady flow and to rebuild the orientation field in bad caliber regions having direct flow.

### Sparse auto encoder algorithm

It carries three hidden layer and straightly impact the categorization result. It involves input, hidden and output layer. In Sparse Auto Encoder orientation field is used as categorization feature. There are specific rules for choosing a position field such as our input because by determining the number and location of the different points, the result of the separation is quite complex. The stand field is part of a global feature of fingerprints, which can take advantage of ridge flow pattern and ridge type. The Gabor filter responses are often used to encode a central point in a process based on the Finger Code. This method provides 99% accuracy when considering the second phase of fingerprints.

## Conclusion

Reconstruction of the appearance of fingerprints is done to obtain the image of the first fingerprints of the given input i.e., set in input. Most importantly there are three main reasons for doing so: (1) to demonstrate the need to obtain a minutiae template, (2) to improve the interoperability of fingerprint templates produced by various combinations of sensors and algorithms, and (3) to develop fingerprints combination. Specifically, in this review paper we focus on the various algorithm techniques used for image reconstruction of fingerprints, how these methods are used, what their process and accuracy are and the errors. Although the reconstructed fingerprints are very close to the original fingerprints when the minutiae were removed from the stand-up case, the ridge frequency field, and the minutiae distribution, it still works hard in some cases including false images for analysis. Future work will be considered to produce realistic fingerprint images for better testing.

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