

# A Survey on Latent Fingerprint Enhancement via Image Decomposition Techniques

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**ABSTRACT:** The Latent fingerprints are used for criminal identification which is lifted from surfaces of objects at crime scenes play a role in identifying aspects in the crime scene investigations. Latent fingerprint images are usually of poor quality with unclear ridge structure and various overlapping patterns. Latent fingerprints, or simply latent, have been considered as cardinal evidence for identifying and convicting criminals. The amount of information available for identification from latent is often limited due to their poor quality, unclear ridge structure and occlusion with complex background or even other latent prints. Latent fingerprint images are usually of poor quality with unclear ridge structure and various overlapping patterns. Sparse image model assumes that most local image patches can be well approximated by a sparse linear combination of elements, the so-called atoms. The collection of these elements is called a dictionary. In this paper proposes a latent fingerprint enhancement algorithm by the total variation model approach. The total variation model extracts the latent fingerprint into cartoon components and texture components. Dictionaries are constructed with a set of Gabor functions to capture the characteristics of ridge structure and multi scale patch-based sparse representation is iteratively applied and reconstruct high quality fingerprint image.

**KEYWORDS:** Latent Fingerprint, Dictionary, sparse representation, multi-scale patch, Gabor transforms function.

## I. INTRODUCTION

Latent fingerprint identification plays a critical role for law enforcement agencies in identifying and convicting criminals. An automated fingerprint identification system is the process of fingerprint segmentation. Based on the procedure of various fingerprint images can generally be divided into three categories, namely, rolled, plain and latent. Plain fingerprints which are acquired by pressing the finger on a flat surface. Rolled fingerprints which contain almost all of the ridge details and that are captured by rolling a finger from nail to nail on a paper. Latent fingerprints which are simply lifted from surfaces of different object touched or handled by a criminal which can be important source of evidence in crime scene investigation. Rolled prints and plain prints are usually of good for visual quality and contain sufficient information for reliable matching. Latent fingerprints through an enhancement stage which removes various overlapping patterns, connects broken ridges and separates joined ridges. This ridge and valley structure of latent fingerprint images are not clearly visible to the naked eye but may be detected with some chemical and physical methods.

Latent fingerprints containing more background noise and non linear distortion due to pressure variations as compared to plain and rolled fingerprint images. Image enhancement is a pre-processing step which is used to improve the quality of the image by removing blur and noise. Latent fingerprints are the finger skin impressions left at the crime scene by accident. Latent fingerprints have been used as an important evidence to identify criminals in law enforcement agencies for more than a century. Before introduction of automated fingerprint identification system (AFIS), latent fingerprints were manually matched against previously enrolled full (rolled or plain) fingerprints by latent examiners to find the suspects.

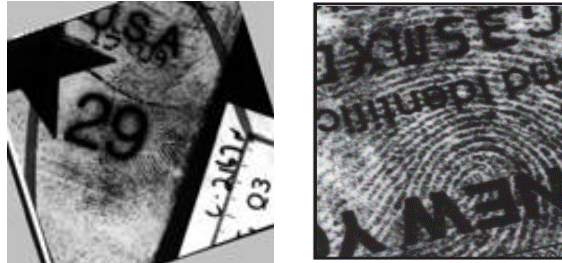


Fig: 1.1 Latent Fingerprints

The Emergence of AFIS significantly improved the speed of fingerprint identification and made the latent identification against a large fingerprint database feasible. Tremendous advances have been made on developing AFIS for full print to full print matching. However, compared to the rolled and plain fingerprints, latent fingerprints are usually of low image quality, caused by unclear ridge structure, uneven image contrast, and various overlapping patterns such as lines, printed letters, handwritings or even other fingerprints, etc. Due to the low image quality, automatic feature extraction is still undesirable for latent fingerprints and manually marked by latent examiners for identification.

Fingerprint Images	Description
<p>Patent Prints</p> <p>Plastic Prints</p>	<ul style="list-style-type: none"> <li>• Visible prints that occur when a substance on the skin of a finger comes in contact with the smooth surface of another object. Eg: Blood on his hands.</li> <li>• Visible imposed prints that occur when a finger touches a soft, malleable surface.</li> <li>• Fingerprints that are freshly painted on coated or those that contain wax, gum, blood etc.. and retain the finger ridge impressions.</li> </ul>
<p>Latent prints</p>	<ul style="list-style-type: none"> <li>• Fingerprint impressions secreted in a surface or an object are invisible to the naked eye.</li> <li>• When the finger touch other body parts, moisture, oil and grease to the ridges.</li> <li>• Techniques provided for identification of these types of prints are lasers, powders and various light sources.</li> </ul>

Fig: 1.2 Types of various Fingerprint Images

## II. RELATED WORK

The interleaved ridge and valley flows of fingerprint form a sinusoidal shaped plane wave with well-defined frequency and orientation in a local neighbourhood. A Gabor filter, which is defined with a sinusoidal plane wave tapered by a Gaussian can capture the periodic, non-stationary nature of fingerprint ridge structure. Gabor filtering is widely used for fingerprint enhancement. In the method local ridge orientation and frequency are first estimated at each pixel based on a local neighbourhood. Then a Gabor filter is tuned to the local orientation and frequency and applied on the image pixel to suppress the undesired noise and improve the clarity of ridge structure. This method requires reliable estimation of local ridge orientation and frequency, which is challenging for poor quality fingerprint. Another interesting technique based on Short Time Fourier Transform (STFT) analysis was proposed to perform contextual filtering in the Fourier domain for fingerprint enhancement. The traditional 1D (one dimensional) time-frequency analysis is extended to 2D fingerprint images for short (time/space)-frequency analysis. The probabilistic estimates of the foreground region mask, ridge orientation and frequency are simultaneously computed from STFT analysis. The full contextual information including local orientation, frequency and angular coherence is utilized for fingerprint enhancement.

### III. IMAGE DECOMPOSITION

A Proliferation of Image Decomposition Techniques in Latent Fingerprint enhancement. Here highlight some of the key contributions.

In [1] the Biometric recognition Systems are the automatic recognition systems which uses the physical characteristics of a person like finger print, hand geometry, face , voice and iris. These systems overcomes the drawbacks of the traditional computer based security systems which are used at the places like ATM, passport, payroll, drivers licenses, credit cards, access control, smart cards, PIN, government offices and network security. The biometric recognition systems have been proved to be accurate and very effective in various applications. The biometric features can be easily acquired and measured for the processing only in the presence of a person. Hence these systems are proved highly confidential computer based security systems. Law enforcement agencies routinely collect records of all apprehended criminals in two forms: rolled and plain (or slap). Rolled fingerprints are obtained by rolling a finger from nail to nail to capture the complete ridge details on a finger while plain fingerprints are captured by pressing down a finger on the at surface of a fingerprint card. Another type of important fingerprint identification involves searching latent fingerprints against reference fingerprint databases. Latent fingerprints (or simply latent) refer to the fingerprints captured at crime scenes, and are regarded as an extremely important source of evidence in crime scene investigations to identify suspects. Unlike rolled or plain fingerprints, latent are often of poor quality; latent impressions typically contain partial ridge patterns of a finger, incomplete or missing ridge structures, mixture of ridge pattern and complex background noise or friction ridge structures from other fingers.

In [2] Image decomposition and restoration for blurred images are the significant challenges in image Processing. Using bilateral filter, image is decomposed into two meaningful components. One is the cartoon component which is often called as geometrical part or sketchy approximation. Other is the texture component which is often called as oscillating part or small scale special pattern. Image restoration for blurred images with or without missing pixels can be performed using median filter and conservative filter. Median filter is a nonlinear digital filter which is often used to remove noise. It preserves the edges while removing noise. Conservative filter is also a non-linear smoothing filter. It ensures that the value of the output pixel is within the bounds of its neighbours. Image decomposition and restoration are the two important problems in image processing. In image decomposition, image is decomposed into two meaningful parts. One is the sketchy approximation or geometrical part of an image which is called cartoon component and the other is the small scale special patterns or oscillating part of an image which is called texture component. The main task is to extract the cartoon and texture parts from the degraded images. Image restoration is the process of improving the quality of the image and eliminating the degradation parts. It is the recovery of an original image  $x [m,n]$  from a given degraded image with or without missing pixels  $y [m,n]$ .

Degraded image is restored to its original quality by inverting the physical degradation parameters such as linear motion, defocus, additive noise and atmospheric degradation. The difficulty for latent fingerprint segmentation mainly lies in two aspects. First, the fingerprint is usually of very poor quality, often with smudged or blurred ridges. It is common that the image contains only a partial fingerprint region, and large non linear distortions exist due to pressure variations. 1) Arch. The big arch is manually marked by crime scene investigators to indicate the possible existence of latent fingerprints in the region encircled by the arch. The arch noise is viewed as the simplest type of structured noise. 2) Line. The line noise may appear in form of a single line or multiple parallel lines.

A single line is detected and removed using methods are based on the concept of Hough transform in [3]. 3) Character. It is the most common types of structured noise in latent fingerprints. Characters may be appearing as font types, sizes and brightness. They can be either handwritten or typed. 4) Stain. It is generated when the fingerprint was inadvertently smeared on a wet or dirty surface. Stain noise often appears in spongy shape with inhomogeneous brightness. 5) Speckle. As compared with lines and characters, speckle noise tends to contain tiny scale structures, which are either regular (e.g., clusters of small dots) or random (e.g., ink and dust speckles). 6) Others. A latent fingerprint may contain other types of structured noise such as arrows, signs, etc. Being similar to arch noise and character noise, they usually consist of smooth surfaces with sharp edges. The line, character and speckle noise types often appeared when the latent fingerprint is lifted from the surface of a text document. For latent fingerprint segmentation, the main challenge lies in how to effectively separate latent fingerprints, the relatively weak signal, from all structured noise in the background, which is often the dominant image component. Additional complexity arises

when structured noise overlaps with the fingerprint signal. The various techniques related to the image decomposition are given below.

Techniques	Advantages
Bilateral (BL) Filter	<ul style="list-style-type: none"> <li>• Low Contrast variation.</li> <li>• Large intensity difference.</li> <li>• Texture is low contrast.</li> </ul>
Weighted Least Square (WLS) Filter	<ul style="list-style-type: none"> <li>• Large Gradient.</li> <li>• Magnitude of gradient is larger at edges.</li> </ul>
Bidirectional Empirical Mode Decomposition (BEMD)	<ul style="list-style-type: none"> <li>• Fine-scale spatial oscillations.</li> <li>• No notion of edge.</li> <li>• Means of oscillations are smooth.</li> </ul>
Total Variation (TV) Model	<ul style="list-style-type: none"> <li>• Fine-scale spatial oscillations.</li> <li>• High variance in range values of neighbouring local extrema.</li> <li>• Detail in oscillations between the local extrema.</li> </ul>

Fig 1.2: Different kinds of Decomposition Techniques

In some smoothing and global modelling methods have been proposed to enable reliable estimation of orientations for enhancement of latent fingerprints. A robust method was proposed for orientation field estimation to improve the performance of latent fingerprint enhancement with Gabor filters. This method applied STFT method to obtain multiple orientation elements in each image block, and a set of hypothesized orientation fields are generated with a hypothesize-and-test paradigm. It required manual mark-up of singular points and the region of interest (ROI) for enhancement. Recently, Feng et al. [5] proposed a robust method to estimate orientation field using the prior knowledge of fingerprint ridge structure, which is represented by a dictionary of reference orientation patches and the compatibility constraint between neighbouring orientation patches. The fingerprint orientation field was computed by a combination of candidates which minimizes an energy function using loopy belief propagation. Gabor filtering was applied to the improvements for enhancement of latent fingerprints. However, the above methods set a fixed ridge frequency to tune Gabor filters for enhancement. In practical applications, it is not always constant in fingerprint image, which limits the enhancement performance of Gabor filtering.

In [4] the total variation (TV) image models, which aim at minimizing the total variation of an image, have been widely studied for image decomposition. Usually, the TV model decomposes an image into two components: texture and cartoon. The texture component is characterized as repeated, oscillatory and meaningful structure of small patterns. Noise is characterized as uncorrelated random patterns. The rest of an image, i.e., the cartoon component, consists of the object hues, sharp edges and piecewise-smooth components. Zhang et al. proposed an adaptive TV model to remove the structured noises for latent fingerprint segmentation. They further proposed an adaptive directional total variation (ADTV) model by integrating the local orientation and scale for fingerprint segmentation and enhancement. These TV based methods decompose latent image into texture and cartoon components. The texture component mainly consists of the oscillatory fingerprint ridge patterns while the cartoon component contains the left unwanted contents, i.e., structured noises. Latent fingerprint segmentation and enhancement are performed on the texture component with the structured noises removed. However, it is not easy to reliably estimate the local parameters (i.e., ridge orientation and scale) of Adaptive Directional Total Variation model for latent images of poor quality. In addition, the noise corrupted regions are not restored and the extracted fingerprint pattern is usually very weak, which will limit the performance of latent fingerprint identification. A dictionary based method was proposed to enable reliable estimation of ridge orientation and frequency fields and facilitate the automatic segmentation and enhancement of latent fingerprints. The TV model was first applied to remove the piecewise smooth and structured noises. Then, both coarse and fine ridge structure dictionaries were learnt from a set of high quality fingerprint patches and used to reconstruct

the ridge structure of latent image. Finally, the orientation and frequency fields were estimated with the reconstructed patches and used for latent fingerprint enhancement by Gabor filtering. Although reliable estimation of ridge orientation and frequency can improve the performance of latent fingerprint enhancement, there are two inherent limitations in these methods. The Gabor filtering with correct orientation and frequency parameters can work well to enhance the ridge clarity; it fails to restore the ridge structure destroyed by heavy structured noises.

In [6] the representative algorithms for fingerprint orientation field estimation. Local estimation approaches compute a local ridge orientation using only the neighbourhood pixels around. Gradient, Silt-based and Local Fourier analysis are three most representative methods. Gradient based approaches compute local orientation by summarizing gradients of local neighbourhood. Silt-based methods choose the direction with smallest intensity variation as the local orientation.

In [7] Prior knowledge of fingerprint orientation fields learnt from many orientation fields as new regularization method for orientation field. Dictionary based algorithm proposed by Feng et al. [7] and localized dictionaries based method proposed by Yang et al. are two representative approaches. Feng et al. constructed an orientation patch dictionary from a set of manually marked orientation fields, so that noisy orientations can be replaced by the closest orientation patches found in the dictionary. Yang et al. extended and constructed localized dictionaries by introducing fingerprint pose and spatial constraint. That is, constructing a set of independent dictionaries of orientation patches for each location, so that orientation patches which are not likely to be in that location will not be looked up. Dictionary based and localized dictionaries based algorithms both show promising performance in correcting and smoothing fingerprint orientation fields.

In [8] the main challenging problem for latent fingerprint enhancement is to remove various types of image noises while reliably restoring the corrupted regions and enhancing the ridge clarity and details. Sparse representation on redundant dictionary is a promising method for image reconstruction especially from the noisy image. As a powerful statistical image modelling technique, sparse representation has been successfully used in various image processing and recognition applications. A latent fingerprint enhancement algorithm via multi-scale patch based sparse representation, which consists of two main stages. First, the TV model is used to decompose latent image into cartoon and texture components. The cartoon component with most of the irrelevant contents is discarded, while the texture component contains the weak latent fingerprint and is extracted for further enhancement. Second, instead of using Gabor filtering, a set of Gabor elementary functions with various parameters are used to build the basis atoms of dictionary and the texture component is reconstructed via sparse representation for latent fingerprint enhancement. The patch size is a critical parameter for fingerprint reconstruction via sparse representation. Large patch can suppress the noise better while small patch can preserve the details of ridge structure. To achieve both noise robustness and detail preserving, a multi-scale patch based sparse representation by gradually increasing the patch size and dictionary scale for iterative reconstruction of high quality fingerprint.

#### **IV. CONCLUSION**

Latent fingerprint images are usually of poor quality, corrupted by various kinds of noises and overlapped with non fingerprint patterns. The objective of latent fingerprint enhancement is to remove the irrelevant contents while enhancing the clarity of fingerprint ridge and valley structure, which can be considered as an image de noising and restoration problem. The Total Variation model is applied to decompose latent image into texture and cartoon components. The cartoon component, which contains most of the irrelevant contents and structured noises, is discarded. Second, latent fingerprint image is reconstructed via multi-scale sparse representation from the texture component. The fingerprint image representation can be initially reconstructed with sparse representation on small patch to preserve the ridge details. Image is decomposed by the Total Variation model and the multi-scale patch based sparse representation is iteratively applied on original latent fingerprint image to construct the high quality fingerprint image. The global structure has a certain degree of regularity, which can be used to guide fingerprint enhancement. Thus the optimization algorithm is ensured the global ridge structure clarity with more effectively and hence it increases the quality of Latent fingerprint images.

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