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Evaluation of Fingerprint Enhancement Techniques Used by Crime Scene Investigation

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Ozet

Bu çalışmada, olay yeri inceleme sürecinde toplanan maddi delillerden olan parmak izi incelenmiş, özellikle olay yerindeki parmak izinin toplanma süreci değerlendirilmiş, parmakizi analizi ve iyileştirilmesinde kullanılan teknik ve yöntemler detaylı olarak araştırılmıştır, 2007-2017 yılları arasında yapılan akademik çalışmalar ve elde edilen başarı oranları ile geliştirilen tekniklerin kıyaslanmaları yapılarak, elde edilen sonuçlar değerlendirilmiş ve bazı önerilerde bulunulmuştur.

Anahtar Kelimeler

Olay yeri, biyometrik doğrulama, parmak izi, iyileştirme, ön işleme, son işleme, uyarlama.

Abstract

This study focuses on fingerprint, which might be material evidence, gathered during the crime scene investigation. The process of collecting fingerprints at the crime scene has been examined. Improvement techniques and methods used in fingerprint analysis have been investigated in detail. The studies conducted between 2007-2017 have compared according to success rates with development techniques. The results have been obtained and some recommendations have been made.

Index Terms

Crime Scene, biometric identification, fingerprint, enhancement, pre-processing, post processing, adjusting

I. INTRODUCTION

Crime scene expresses the dynamic region where the process of the event is analyzed, criminal suspect and victim can be identified. Any material obtained during the crime scene investigation in order to reveal the crime scene-victim- wrongdoer is called the finding. Crime scene investigation is a research to help clarify the crime of the incident, to find material evidence for the identification and evaluation of murderer or crime process [1,2].

Material evidence collected from the crime scene has certain characteristics [1]. These are:

- It is used to revive the committed crime.
- It is used to find the identity of the victim or to determine the relationship between the crime scene-victim-wrongdoer.
- It can be used as evidence in the court at the time of investigation, after being processed in laboratories.
- It has a material structure and can be alive or inanimate.

The main purpose of the crime scene investigation is to collect data, audio recordings, witness statements that point to the offense etc. without any change and deterioration. If the material evidence gathered from the crime scene is to be grouped [2]:

- Biological evidence; usually composed of body parts and body fluids such as blood, hair, semen, saliva, urine, feces, tissue fragments and bone, skin rashes and dandruff, nasal fluids and sweat
- Biometric evidence that characterizes the body such as fingerprint, footprint, palm print, tooth print, sound, image, data evidence, hand writing
- Inanimate evidence such as wheel trace, tool trace, traces of firearms, explosives, flammable and combustible substances, drugs, medicines, paints, shooting residues

Biological and biometric data collected from the crime scene are definitive proofs in determining the offender. DNA analysis is performed using biological evidence. It is briefly a person-specific descriptive code and is found throughout the body tissues. In addition, biometric evidence is also person-specific [3].

Biometry is used for two main aims: verification and identification. Verification is used in order to access to high security areas and access control such as airports, laboratories, hospitals, banks etc. In the identification process; system compares the biometric properties of the person with the other biometric properties of the previously stored databases and tries to find out who he/or she is. As a result, either the person is identified or the person being compared is not registered in the current database. For this reason, identification is usually used for the analysis of collected data in criminal proceedings [4].

Fingerprints taken as a result of criminal analysis cannot be processed like fingerprints used in other biometric applications, so biometric data are not used directly. Due to environmental conditions, the fingerprint data may not be enough capacity to provide the necessary properties, collected data may be just fingerprint's small part instead of the entire fingerprint or the fingerprint may not have sufficient quality

due to noise in the environment. For this reason, before the characteristic features of the fingerprint are collected [5]:

- Normalization, reinforcement, thinning, orientation calculations
- Finding the core point
- Extraction of minutiae points and determination of faulty minutiae points
- Finding reference points and matching procedures

Examination of the literature studies show that these stages have been carried out for identification process. As a result; some operations such as noise removal from fingerprint data, fingerprint separation from the crime scene background, deleting incorrect values from the fingerprint etc. directly affect the end result of who the fingerprint belongs to. For this reason, it is necessary to carry out all or some of these steps mentioned above. In Figure 1, the steps applied for a fingerprint from crime scene are visualized.

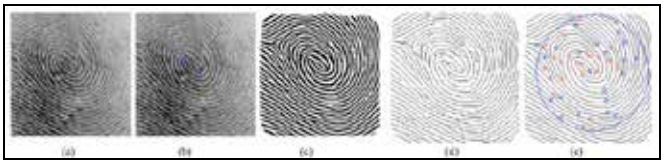

Fig. 1. Fingerprint analysis steps (a) introduction image, (b) reference points, (c) binarization, (d) thinning and enhancing, (e) finding minutiae points and identifying faulty minutiae points

Sequence of operations as mentioned above is expressed fingerprint image enhancement. In this study; collection and analysis of the fingerprint from the crime scene is investigated. In section 2, it is emphasized how fingerprints are used as identifiers. In section 3, preprocessing, adjusting and post processing, which are image enhancement steps, are mentioned and the techniques and methods used in these steps are analyzed according to the obtained success rates. In the last section; the results and suggestions obtained at the end of the study are shared.

II. FINGERPRINTS COLLECTED FROM THE CRIME SCENE AS IDENTIFIERS

All of qualifications used to identify someone and distinguish him or her from others are called identity. Putting forward these properties to know the person who is dead or alive is called as identification. Criminal investigations are very important for illuminating the event, punishing of the criminal, determining of victim or criminal who is dead and alive and people's life in peace and security. To illuminate the criminal events, it can be utilized factors such as age, gender, height, body weights, skin, hair, eye color, fingerprints, teeth trace, footprints, palm prints, etc. of the person for identification. Some characteristics such as age, gender, body weight, hair, and eye color among these elements are not determinants when it is difficult to recognize someone. For this reason, it should be used the biometric data to get more accurate result in recognition. There are lots of biometric data types that are common in the crime scene. Some of them are [1,2]:

- The reliability of recognition systems is quite high for DNA, which is obtained by utilizing the hair, saliva, blood, hair, teeth and bones collected by the scene investigation teams. Despite the fact that identification with DNA is fairly reliable, the collection and analysis of these data is very long and troublesome [1].
- The palm prints and footprints are obtained on the same conditions at crime the scene. These traces are similar to each other. So, while these traces are analyzed, it is difficult to distinguish from each other. In this respect, it is not useful for identification [1].
- When the criminals do not use any hand covering such as gloves, they leave the trace on the crime scene. These traces occur when sweat or skin oil comes into contact with the surface. These traces can be obtained easily by the crime scene teams at places like doors, locks, glass, window tops and edges, cups, plates, forks, knives, pillars, switches, fuses, light bulbs thought to have been loosened with the aim of being extinguished, clothes, shirt catches in case of strangulation, safe locks, drawers, glass, tiles and so on. The fingerprints in crime scene are made visible to the current methods and transferred to digital platform. Then fingerprint enhancement methods are applied [1].

The fingerprints obtained from crime scene are divided to three classes according to surface texture and whether they are visible or not [6,7]. These fingerprints types are explained in below:

- Plastic fingerprints are three-dimensional traces formed by touching finger of criminal or victim on soft surface such as soap, candle and wet paint [6,7].
- Visible fingerprints are traces formed by touching finger contaminating with a substance such as paint, blood, dust, flour, etc. These traces are investigated either naked eye or using alternative light sources. It is ensured that use of various chemical powders is more pronounced in case fingerprint appears. After the trace is made clear, photographing and transparent tape method is used to get it from where it is [6,7].
- Latent fingerprints are the invisible traces left by finger, which is not on the soft surface, and not contaminate with colorant. These traces transmit from the finger to the surface, thanks to the fluid released from the pores. Investigations are conducted on possible surfaces by assessing the nature of the event, the crime shape and the behavior of criminal at the crime scene. So it is tried to find a trace on these surfaces. To obtain such fingerprints clearly, it is necessary to use chemical methods, fingerprint powder, and alternative light sources [6,7].

The Methods of fingerprint acquisition on surfaces by the crime scene teams requires expertise. It is very important for the recognition process to be performed by experts and using the correct techniques while collecting traces. In the first

stage, they investigate the fingerprint on the visible surface. No matter how visible it is visible, they try to obtain smoother images. So, it is necessary to techniques providing image quality increase such as chemical methods and alternative light sources [7].

One of the most important methods used to find and collect latent fingerprints is to use chemical in movable or unmovable places. The obtaining clear fingerprints vary according to the environment, chemical methods, the skill of the experts, sensor limitations, intrinsic aging, factors like cuts, wrinkles, injuries and intrinsic aging. If the chemical methods to be used are not correctly selected, the traces may be distorted or disappear completely. For this reason, before the powers are used, alternative light source and cyanoacrylate should be used on movable or immovable surface. After fingerprinting becomes apparent with these methods in order to transfer digital media, photographing and transparent tape method is used to get it from where it is. However, the degradations based on sensor limitations are resolution, signal to noise ratio and cleanliness causes a reduction in image quality. Along with that, although the crime scene investigation team works meticulously, low quality images are obtained from the crime scene due to factors such as aging, cutting, injury, etc. For these reasons, the recognition system gives incorrect results. In order to clarify the event, identify the victim or criminal, punish the criminal, the fingerprint must be subjected to the enhancement process before matching operations. So, it is primarily necessary to know fingerprint structure and its properties in order to apply enhancement techniques correctly [7].

Fingerprints begin to form when baby's fingers touch mother's uterus. Fingerprints are unique patterns produced by ridges and valley appearing on the surfaces of fingers. The ridges are defined as the dark area in a fingerprint, while the valleys are defined as white area whose region is between two contiguous ridges [4].

Fingerprints are separated into two classes, local and global, depending on the flow of the ridges or the shape and relationship of the ridges. While local characteristics are used to match and verify, global characterizations are used to match, verify and classification [4]. In Figure 3 the local and global characteristics are shown and explained in bellow.

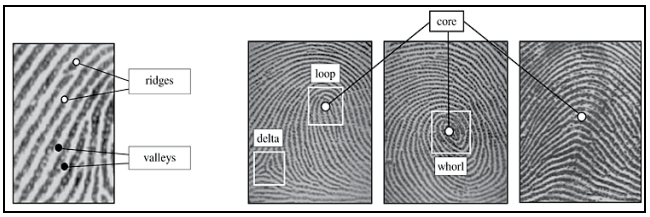

Fig. 2. Global and local characteristic in fingerprint

Global characteristics: Global characteristics formed by depending on ridges or the shape and relationship of the ridges are separated to four class including delta, loop, whorl and arc.

Fig 3. Global characteristics (loop, whorl and ark)

Local characteristics, which are known as a minutiae are local discontinuities in the ridge pattern and provide features to make a personal identification. Although there are many characteristics to be identified, the most of these characteristics are not commonly used to make a personal identification. Only two local characteristics of them, which are ridge ending and ridge bifurcation, are sufficient for identification. Ridge ending is abruptly the ending of ridge on finger. A ridge bifurcation knows as a ridge forks or diverges into branch ridges [8]. Automatic fingerprint matching is compare these minutiaes and their relationships to make personal identification [4,8]

As can be seen, fingerprints can be analyzed according to global characteristic such as loop, whorl and arc, and local characteristic such as bridge, island, line and bifurcation. Then identification is performed according to these characteristics

III. FINGERPRINT ENHANCEMENT TECHNIQUES

While fingerprints are obtained on the crime scene, environmental changes, chemical methods, surface, sensor limitation, age, cuts, and injuries causes the deterioration of image quality image [7]. All of the degradation makes difficult to extract feature. The ridges, which are in fingerprint pattern, contain information of characteristic features for minutiae extraction. The degradation affects these structures. So, the ridges may not strictly continuous due to small breaks (gaps) and contiguous ridges may not well be separated due to the presence of noise. Thus enhancing the fingerprint images are often employed to reduce the noise and become the ridge structures more apparent. The aim of image enhancement techniques improves the clarity of ridge structure in input fingerprint image [4,8,9-31]

In literature, many methods have been proposed to enhance images. However, there is not standard approach used to completely improve fingerprint images. In this works, techniques used in the literature are divided into three categories consist of preprocessing, adjusting and post-processing respectively and techniques in literature and shown in figure 1. In bellow, the methods used in each step are explained and their advantages *and disadvantages are discussed.*

A. Pre Processing Techniques

Pre-processing step can be defined as conversion operations on the data to remove the systematic errors in the aggre-

gated data. This step is performed before applying direction, frequency and filtering techniques in fingerprint images. [8-30]. Correction of errors in data and elimination of redundant data directly affects the recognition process. There are many different approaches for pre-process. One or more of these approaches may be used in this phase. The studies show that; the preprocessing step ensures that the ridges are more pronounced when extracting features and combinations of different techniques have different success rates. When the examined studies are summarized the following headings have been obtained. These are [9-31]:

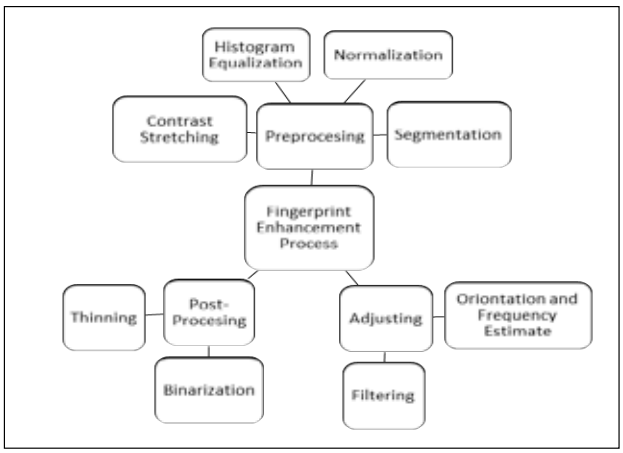

Fig. 4. Enhancement techniques in fingerprint image

Contrast Stretching: Contrast is an important factor in the process of evaluating image quality. Contrast is defined as the difference between visual objects that allow the object to be distinguished from other objects and from the background. Contrast stretching is general phase and linear and nonlinear transform functions such as image negatives, logarithmic transforms, power law transformations and piecewise linear transformations usually are used [16,30].

In study of Hari et al. [30] they have used unsharp masking which is a contrast-stretching scheme and they offer more enhancements in contrast but yielded broken ridges, especially in areas where the ridges are lost in noise. Draa et al. have proposed a new Artificial Bee Colony (ABC) algorithm for image contrast enhancement and have been improved for color image enhancement and their test results are promising [32].

Histogram equalization: Histogram is a graphic, which shows each color value in a numerical image. The brightness and tones in the picture can be determined by using this chart. Histogram Equalization is a method that improves the contrast in an image, in order to stretch out the intensity range. The main purpose of histogram equalization is trying to maximize the image contrast by applying a gray level transform. Histogram Equalization and contrast stretching can be considered as intertwined. While contrast stretching is interested with increasing the difference between the maximum-minimum intensity values, histogram equalization is interested about modifying the intensity values of pixels in image to ensure that the histogram flattened [9,29,31].

In study of Tang et al. proposed Adaptive Image Enhancement based on Bi-Histogram Equalization (AIEBHE) which divides the histogram into subgroups to preserve average brightness and their technique outperforms other histogram-equalization-based enhancement techniques in terms of preservation average brightness [33]. In proposed of Lai et al. MSHE method, textured regions in image should be highlighted and impact of smoother regions should be suppressed. Their experimental results show that; their method is quite competitive if any comparison to other method is made such as HE, BBHE [34].

Normalization: It is commonly used in the image enhancement process and can be thought of as one of the basic steps for image processing. Normalization is a phase in the process that can directly affect the success rate according to the way it is applied. If the mean and variance are calculated based on the entire image, successful normalization operation cannot be performed because of average mean and variance values are used in low-quality region. When local optimization is examined; image is divided into regions and the average and variance of each region are calculated. Since these values are used in the relevant sections, the results of the other section cannot be affected. Thus, the success of the normalization process increases [9,15,16,18,20,22,28,30].

In study of Saravanan et al. local histogram equalization and local normalization is used and normalization is performed in order to reduce the variation in gray level and obtain an image with a pre-specified mean and variance [9]. In study of Khan et al. they have proposed a method, which comprises of normalization, ridge orientation estimation, ridge frequency estimation and filtering stages. Their normalization step has provided avoiding imperfections in the fingerprint capture [35].

Segmentation: The techniques used to extract the fingerprint images from its background are called the segmentations. Since undesired background processing takes more time in enhancement, it is not useful. The aim of it is to reduce size of data, the time consumption of the image enhancement, facilitate the extraction of the minutiae Eliminating the region ends in minimization of number of operations in fingerprint image [16,17,20-22,28,31].

Balti et al. used to the K-means segmentation and Fuzzy c-means which are an unsupervised clustering technique. So it has been observed that it can reliably segment the fingerprint image other techniques [17]. In study of Gupta et al. proposed a slap fingerprint segmentation, which can accurately segment the fingerprints. This approach is used to eliminate several non-fingerprint components, improve its performance. It has been observed that it can correctly segment the fingerprints from the slap-images with an accuracy of 99.40% [36].

B. Adjusting Techniques

Adjusting step is defined as the extraction of intrinsic image and filtered image to extract correct feature extraction. İn this processing, firstly intrinsic information including direction and frequency is obtained and then according to intrinsic information filtering is applied. There are many dif-

ferent approaches for post-process. One or more of these approaches may be used in this phase. The studies show that; this process is the most important step in enhancement. Obtained correct orientation and frequency is improved the success of filter. The previous process defined as preprocessing does not enhance depend on orientation and frequency. So it cannot guarantee getting correct feature. For this reason, pre adjusting is required. When the examined studies are summarized the following headings have been obtained. These are [9,31].

Estimation of Orientation Field: Orientation field is described as the basic structure used in enhancement, which represents the ridge flow of fingerprint. It is important role in enhancement, feature extraction and as a consequence the accuracy of the recognition. The aim of estimating orientation field is to aid to extract correct feature extraction. İt has been realized that defining orientation field at the block level is better than at the pixel level in terms of reducing computational and storage complexity. By filtering along the ridge orientation, quality of fingerprint is improved. However, orientation estimate in latent fingerprint that is obtained from the surfaces of object at crime scenes is too hard since it is poor quality. In this situation reduces the accuracy of fingerprint identification [9-12,14,15,18-21,23,25-27].

In study of Bian et al. they proposed fingerprint orientation field extraction method based on quality grading scheme. In this approaches firstly they have computed the orientations of the higher quality blocks and then are computed the blocks with the lower quality. In other words, after the quality priority of the blocks has been determined, block orientation is estimated orientation. The aims of them spread the higher-quality block an orientation into the neighbouring lower-quality blocks. It has been realized that it cannot guarantee the accuracy of the assessments exactly [37]. In study of Luping Ji they used to projective distance variance of ridge in order to estimate block direction. So, they estimated block direction without using all block. This method is applied to binary image. It has been released that it is better result in terms of performance improvements in compare to other methods. But, the increase in noise intensity is caused to decrease estimation accuracy of orientation field and prolong the processing time [38]. In study of Chikkerur et al. in order to estimate orientation, they proposed a probabilistic approximation of the ridge orientation using short time Fourier analysis. Orientation and frequency information of images is obtained simultaneously. The estimation of orientation can be wrong due to a crease in the fingerprints that spans several analysis frames. However, if there is a crease in the fingerprints that spans several analysis frames, the orientation estimation will still be wrong. To overcome this problem, the orientation of its immediate neighborhood is used. Also, it approach does not regard to local discontinuities [23].

Estimation of Frequency: Frequency in fingerprint image is defined as average distances of inter ridges. As is in orientation field, frequency map cannot extract in the background region. Before estimation of frequency, by applying pre-processing consists of contrast stretching, histogram equalization, normalization and segmentation, the quality of poor region can be enhanced as much as it can be cured or during the segmentation phase of these processes in poor quality image is defined background. So extraction of feature does not occur. Since frequency map is used with contextual filter, it is important that frequency is obtained after preprocessing is applied. Obtaining frequency map in this direction is improved the success of enhancement. The frequency of image is used for extracting reliability minutiae in enhancement [9-12,15,18,21,23-26].

In study of Saravanan et al. in order to obtain frequency, they used to the 2-D Fourier Transform domain approach. This approach makes the process forceful. Also, it reduces the cost of calculation thanks to simultaneous computation of orientation and frequency. Through extraction the frequency of image with this approach, high achievement is obtained in enhancement. A pseudo-spectral fusion approach to fingerprint matching was proposed in [9]. A pseudo-spectral fusion approach depends on orientation and frequency. They developed to two methods in spatial and frequency domain in order to get frequency.in spatial domain methods, before obtaining frequency of image they performed median filter. The aim of using median filter is to eliminate values corresponding to pits and holes and normalizes the curve to have zero-mean They proposed 2-D Fourier Transform to estimate the frequency of image in frequency domain.it has been realized that proposed approach is the most efficient compare to other methods [39]. In study of Chikkerur et al. in order to estimate frequency, they proposed algorithm using short time Fourier analysis. Unlike most algorithms, frequency does not depend on orientation information. Orientation and frequency information of images is obtained simultaneously [23].

Filtering techniques: Filtering is a technique used to eliminate distortions occurring during the image formation. The aim of filters is to emphasize the gray values of pixels or prevent appear. The aim purpose of applying the filtering process in fingerprint images is to remove the noises by maintaining the continuity of the ridge and joint the breaks. So, it has been come to the forefront that filters must be applied it depends on direction. In this way, the feature extraction is performed correctly. In literature, there are the filters applied in the spatial field frequency domain for fingerprint enhancement. Despite the fact that the direction-dependent filters implement in both areas, the filters in the spatial domain cause computation complexity. So, filters in the frequency domain are more useful [9,16,18-28,20,31].

Table 1. Fingerprint Image Enhancement Techniques, Used Methods, Success Rate and Used Dataset

Ref. No	Purposed	Used Techniques	Success Rate	Data Set
9	Extracting and compressing the fingerprint feature	Local Histogram Equalization/ Local Normalization/ O-F Estimate/ Binarization	Compression Rate: 85%	FBI database
10	Estimating the parameters in an effective way/ Enhance the fingerprint	O-F Estimate/ Gabor Filter	EER: 11.5½	FVC2004: DB1_A
11	Improving the clarity of ridge structures in recoverable regions	O-F Estimate/ 2D Low pass Wiener Filter/ Second Derivative of Gaussian Filter	True Core Points: 74%	FVC-2004: DB1-A
12	Extracting the fingerprint characteristics better/ Improving the percentage of fingerprint identification/ Assessing the enhancement alg.	Gray Level Equalization/ O-F Estimate/ Gabor Filter	-	FVC2002 DB3
13	Enhancing the fingerprint	PCA Filter/ Thinning	-	-
14	Improving the clarity of the ridge structures in the recoverable regions/ Marking the unrecoverable regions for further processing	Orientation Estimate/ Gabor Filter/ Gaussian Filter/ Binarization/ Thinning	Orientation Extraction: 0.022s Enhancement Method Based On Gabor: 0.033	FVC2004 Databases/ live-scan database
15	Enhancing the fingerprint	Normalization/ O-F Estimate/ Gabor Filter	Better Perfor. Comp. to Prev.Works/ Hardware Cost 63.8k Gate	-
16	Enhancing the feature of sharpened image/ Reduces processing time	Normalization/ Segmentation/ Sharping Filter/ Gabor Wavelet Filter/ Binarization/ Thinning	Accurately Enhanced 97.14%	FVC2004
17	Extracting the ROI foreground/ Excluding the background regions/ Reducing the time of subsequent processing/ Avoiding the detecting false features	Contrast Enhancement/ Segmentation	K- Means Class. 75.97% / Fuzzy C- Means Class. 76.67%	100 images taken from database FVC2004
18	Enhancing curved structures in noisy images	Normalization/O-F Estimation/ Curved Gabor Filter	EER: %11.88	FVC2004
19	Obtaining a reliable ridge orientation field/ overcoming some limits of the existing enhancement algorithm	Orientation Estimation/ Median Filter/ Morphological Filtering	AR: 85.32%	FVC2004:DB2
20	Connecting broken ridges/ Remove smears and scars /Separating falsely conglutinated ridges/ Removing the true minutiae/ Improving the contrast of low-quality fingerprint images	Normalization/ Segmentation/ Anisotropic Diffusion Filter/ Compensation Filter/ Angular Filter	Complexity Performance: 24.95s/ Objective Qualıty Measurement: 0.0065	FVC2004:DB4
21	Improving the performance of fingerprint and the accuracy of the estimation	Binarization/ Segmentation/ Gaussian Filter/ O-F Estimation/ Curved Gabor Filter	FAR Reduce 0.25% / FRR Increase 0.5%.	FVC2004
22	Enhancing the image with less computation time	Segmentation/Normalization/ Gaussian Band-Pass Filter	PSNR: 26.48db / Comp.Time: 0.8644 Secs	138 Fingerprint from 46 hetero. population
23	Enhancing fingerprint/ estimating the intrinsic properties of the fingerprint	O-F Estimate/ Contextual/ Non-Stationary Filtering	EER: %7.8 Relative Improvement : %24.6	FVC2002 DB3, NIST
24	Enhancing the true minutiae point/ Remove the wrong minutiae	Frequency Estimate/ Gabor Filter/ Gaussian Filter/ Thinning	Better Perfor. Comp. to Prev.Works	FVC2004/ FVC2002:DB1
25	Overcoming the limitations of traditional gabor filter/ Promote fingerprint enhancement Performance/ Reduce the comp. cost/ Extract the frequency spectrum for each block	O-F Estimate/ Log-Gabor Filter	Total Error Rate Is Less Than 5.3% in FVC2004 DB2/ Total Error Rate Is Less Than 4.8 % in FVC2004 DB4	FVC2004:DB2/ FVC2004:DB4
26	Extracting five feature from fingerprint/ Analyzes image quality with clustering method using ward's algorithm	O-F Estimation/ Adaptive Filter/ Thinning	Exec. Time:0.553 s/ Genuine Accept Rate 96% at in 10% FAR	NIST DB4/ Collected dataset at India University
27	Overcome unwanted defects fingerprint recognition system	Orientation Estimate/ Directional Low pass Filter/ Binarization	Executive Times: 0,540 s	FVC2000
28	Propagating good spectra of enhanced ridges to lower-quality regions.	Segmentation/ Normalization/ Gaussian-Matched Filter/ Binarization	Average Equal Error Rate In 8 Out Of 15	FVC2000-2002-2004-2006
29	Enhancing feature extraction for low-quality fingerprint images by adding noise to the original signal	-	EER with no Enhancement: 6.55%/ Histogram Equal.: 6.15 %/ SR Enhancement: 5.03%	FVC2004 DB2
30	Enhancement fingerprints in a dark and noisy background	Normalization/ Quadratic Filter	SNR: 2-4 Db	100 test fingerprints
31	Patching of pore holes in the ridges/ Joining discontinuous ridges	Contrast Stretching/ Histogram Equalization/ Binarization/ Segmentation/ FFT/ Averaging Filter	Coloration: 0.5510/ PSNR: 52.8905	VeriFinger Database

In study of Hu et al used the Gabor Filter and STFT together. So they have been observed that it is powerful in improving the low quality fingerprints, creating a more clearly, increasing the accuracy of minutiae extraction and matching [10]. In study of Choomchuay et al. used directional filter including the second derivative of a Gaussian filter and the pyramid technique. It has been observed that it is smoothed the image with this approaches and increased success of true core point detection [11].

In study of Yuanyuan proposed an elliptical Shape Gabor Filter, which is completed successfully via estimating the degree of curvature and the frequency of fingerprint ridge in local areas. Thereby, it has been observed that it is avoided the block effect, achieved the high accuracy rate, get correct and more precise enhancement [40]. In study of Kabir et al used the anisotropic diffusion filter, the compensation filter and the angular filter. It has been observed that it can connect broken ridges, remove smears and scars, separate falsely conglutinated ridges, recover the true minutiae and improve the contrast of low-quality fingerprint images [20].

C.Post Processing Techniques

Post-processing step used to extract the minutiae more easily and quickly can be defined as conversion operation on enhanced image. This process is also defined as the final stage of the improvement of the fingerprint images and is performed after applying pre-processing and pre-adjusting. There are many different approaches for post-process. One or more of these approaches may be used in this phase. The studies show that; even if it has been cleaned and improved, processing of a gray level fingerprint image is very difficult to find minutiae. To be able to perform image analysis more easily and quickly, it is necessary to apply post processing. Thereby performance of minutiae extraction is improved. When the examined studies are summarized the following headings have been obtained. These are [9-31]:

Binarization: Binarization is a procedure that converts gray scale images into binary images. After binarization, each pixel of the gray scale images is assigned to be either black or white, which are expressed, by ridge and valleys. While a fingerprint image is obtained, the image can be obtained at a binary level or a gray level. If images are scanned at the binary image and then extracted minutiae, it may have a loss of data since gray level images have more information than binary images. This causes spurious minutiae to be extraction and the system performance to be decreased. If the correct threshold which is adapts value to the average local intensity is used, applying binarization can be improved the system performance and be extracted the correct minutiae. However, the processing time in gray ones is longer than that in binary ones [9,14,16,21,27,28,31]

Yun et al. have been applied binarization in preprocessing. They offer more effective in terms of the processing time since gray level image have more information than binary image. However, converting binary image without enhancement causes many spurious minutiae and also removes many important features [26]. In study of Saeed et al. they have performed binarization by using a threshold close to the whitish gray color. Their experimental results show that; their approaches quite competitive according to other method, which is, consist of binarization [16]

Thinning: Thinning is defined as reduction the width of ridges to one pixel in order to obtain the skeletons of fingerprint ridges. The aims of the process are to maintain the connectivity of the original shape including the position, direction and length of lines, to make more easily the extraction of minutiae and to increase the reliability of minutiae. It is important to develop thinning algorithm without generating spurious. The basic components to be considered at this stage; it should not generate spurious minutiae, ridge connectivity should be ensured, pixel should be convergences to unit width, computational cost should be reduced [13,14,16,24,26,32].

In study of Ahmed et al. it has been proposed rule-based approaches for thinning. This approaches guarantees symmetrical thinning with high speed however, it does not give a good result for 2-pixel line [41]. Guo et. al have developed an iterative algorithm known as Zhang-Suen's Algorithm. While preserving to belong to the skeleton, it removes all the contour points of the image. However it is ineffective in terms of preserving patterns that have been reduced to 2x2 and after thinning operation cannot guarantee curve [42].In study of Chen et al. They improved to Zhang-Suen's Algorithm. Their experimental results show that; they have overcome problems of Zhang-Suen thinning algorithm. But this algorithm cannot remove to the acute Angle at the line produced by redundancy line [43]. In literature, it is noted that Zhang-Suen's algorithm is the most preferred thinning algorithm compared to other thinning algorithms. But using this algorithm alone does not give the desired result. Thus it is important that modified and improved of this algorithm is used.

IV. CONCLUSION

In this study, use of fingerprints for identification, collection and analysis of fingerprints at the crime scene, techniques and methods of fingerprint enhancement and the steps used in enhancement process were reviewed. Regarding the results obtained in the reviewed studies:

- Three different types of material evidence are collected from the crime scene. These are biological evidence, biometric evidence and inanimate evidence.
- Fingerprint is biometric evidence and has five basic features. These are universality, distinctiveness, permanence, collectability, and performance. By taking advantage of these features, fingerprint is analyzed whether the fingerprint belongs to the person.
- Fingerprints obtained from crime scene are divided to three classes. These fingerprints types are; plastic finger-

prints, visible fingerprints and latent fingerprints.

- Each type of fingerprint is collected from crime scene with different techniques and methods, after that it is transferred to digital media.

- Fingerprints collected from crime scene are evaluated by image enhancement techniques for use in recognition process.

- Image enhancement techniques are performed in three steps. These are preprocessing, post processing and adjusting. All of these steps do not have to be applied, some of them can be applied alone or some of them can be applied in different combinations.

- The studies conducted between 2007-2017 have been examined and it is seen that; image enhancement techniques are divided into sub-steps themselves. During the pre-processing period, normalization, histogram equalization, contrast stretching and segmentation operations can be applied. In the adjusting process; filtering, orientation and frequency estimate operations can be applied. Finally; during post processing; thinning and binarization operations can be applied.

- It has been observed that the data sets used in the studies performed are generally the same. This situation can lead to the similarity of the results. In the studies to be developed, success rates obtained in different data sets should be emphasized.

- There is no obligation to use all the techniques and methods used to improve the image. It is seen in the studies examined that some of these methods have been used in different combinations.

- Every technique in examined studies has been used to achieve a different purpose. Table 1 shows that; the success criterion obtained from studies does not have a single standard. In order to define success rate achieved in the studies; some terms are used such as compression rate, EER, true core points, orientation extraction, complexity performance, objectıve quality measurement, FAR, FRR, executive times, SNR etc.

- There have been available a few studies interested in image enhancement. Because fingerprints detection mechanism is really one of the most difficult and important process for crime scene investigation.

The contribution of this paper is to review the most recent image enhancement techniques and some solutions according to the literature. This study also contributes the authors who want to study image enhancement methods by providing them a comprehensive analysis of used methods. System and application developers can also benefit from our conclusions while developing new software.

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