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# Fingerprint image enhancement by differential hysteresis processing

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**Abstract**

A new method to enhance defective fingerprints images through image digital processing tools is presented in this work. When the fingerprints have been taken without any care, blurred and in some cases mostly illegible, as in the case presented here, their classification and comparison becomes nearly impossible. A combination of spatial domain filters, including a technique called differential hysteresis processing (DHP), is applied to improve these kind of images. This set of filtering methods proved to be satisfactory in a wide range of cases by uncovering hidden details that helped to identify persons. Dactyloscopy experts from Policia Federal Argentina and the EAAF have validated these results.


*Keywords:* Image digital processing; Fingerprint; Differential hysteresis processing

## 1. Introduction

In March 1976, a military junta took control of the government in Argentina. Between 1976 and 1983 our country was under this military dictatorship that was responsible for the disappearances of 30 000 people. When Argentina restored its democracy, people began claiming in order to find out the fate of their missing relatives, victims of the dictatorship. Different human rights organizations have been in charge of finding missing people, and nowadays they are still working to achieve this goal. The Argentine Forensic Anthropology Team (EAAF) and the Division of Missing People are some of these organizations. Their work has focused on investigating cases of persons who disappeared during the last military dictatorship. They attempted to match historical data described in the police files with information about NNs contained in the "Registro Nacional de las Personas" or RNP records [1] and they also cross-referenced the fingerprints of unidentified persons from the "Cadavers File" microfilms with those of disappeared persons obtained by EAAF from the RNP.

The characteristics of each set of fingerprints are coded according to a standard procedure that enables rapid initial comparison between the fingerprints of the disappeared persons and the fingerprints at the police archives. A more rigorous comparison was requested from the fingerprint Division of the Technical Scientific Police when probable matches between sets of fingerprints were identified.

The problem is that most of the fingerprints were taken without any care, they were blurred and their spatial definition was not clear. These features made their classification and comparison nearly impossible. Since 1997 our Laboratory has been helping these organizations solving these kind of problems.

A fingerprint is the pattern of ridges and valleys on the surface of a fingertip. The uniqueness of a fingerprint is exclusively determined by the local ridge characteristics and their relationships. These local ridge characteristics are not evenly distributed. Most of them depend heavily on the impression conditions and quality of fingerprints. Minutiae are the most prominent local ridges characteristics. They are ridge ending and ridge bifurcation. Therefore, the objective

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of a fingerprint enhancement algorithm is to improve the clarity of ridges structures.

## 2. Materials, methods and techniques

The microfilm fingerprint images were digitized via a LEICA DMLB microscope with a LEICA DC100 camera connected to a capture frame board. The images were stored in a AMD-550 MHz, 64 MB RAM, 10 GB hard disk, personal computer by means of a LEICA DC Viewer Software Version 3.1.0.0.

The software used for processing the images included both commercial (Image Pro Plus Version 4.1 from Media Cybernetics and DHP algorithm from Image Content Technology LLC) and custom packages (PDI Version 2.0 developed in our Laboratory using Delphi). The custom software allows the use of filters that are not commercially available.

The purpose of enhancing defective fingerprint images is to transform them into images suitable for a fingerprint expert to analyze. This goal is achieved by finding the processing techniques that are more appropriate for these kind of images. Enhancement techniques have to increase the dynamic range of the fingerprint images without generating any distortion or creating an ‘‘artifact’’ appearance that could obstruct its identification.

Digital enhancement methods can be divided into two broad categories: spatial domain methods and frequency domain methods. Spatial domain techniques refer to the image plane itself and are based on direct manipulation of pixels in an image. The simplest spatial domain enhancement techniques are based on point processing, which modify the gray level of a pixel independently of the nature of its neighbors.

On the other hand, Frequency domain processing techniques are based on modifications over the Fourier transform of an image.

Numerous researches have been carried out [2–6] where mixed processing techniques were employed. Frequency domain methods have been used for enhancing fingerprints, but often this kind of processing requires a personalized image-by-image treatment. This is a disadvantage when a lot of images with different kind of defects have to be processed, as is seen in this case.

In this research, a combination of appropriate techniques in spatial domain were found to produce very satisfactory results for the finger marks under study. Once the parameters were adjusted, this set of techniques work in a broad range of cases saving image-processing time, suitable for the great quantity of fingerprints to be enhanced.

Techniques based on background noise reduction using morphological filters [7,8] and high-pass-Gaussian [9] convolution filters in combination with an algorithm named differential hysteresis processing (DHP) [10,11] were applied.

Next, the first two filters and stressing description of the DHP method are briefly described as follows:

(a) *Background noise reduction filtering*: This non-linear technique is used to even out background intensity variations, as the background color is well known (highly suitable for inky fingerprint). This filter takes a copy of the image, then applies a set of morphological filters to get a background estimate and finally, subtracts background estimate from original. Fig. 1 shows the process.
(b) *Gaussian high-pass filtering*: This filter increases the visibility of the high frequency information that is present in the fingerprint ridges. Moreover, the particular shape of this filter minimizes the distortion that the filtering process introduces in an image. See Fig. 2.
(c) *Differential hysteresis processing (DHP)*: This technique allows extracting and highlighting desired levels of contrast inside of a digital image. This capability can be used to improve and emphasize certain aspects of visual information.

DHP process is applied to hundreds of radial imaginary lines traced from each pixel of image and can be used to amplify or suppress a specific range of contrast information selected. The level of contrast variation that is desired to remove can be specified by a number, named *contrast window size*. Hysteresis Process is applied to each line of pixels, applying specific rules that can modify each pixel intensity value.

An important aspect of the hysteresis process is that the window size may be any value, depending on the desired effect. A small window size will filter out only small

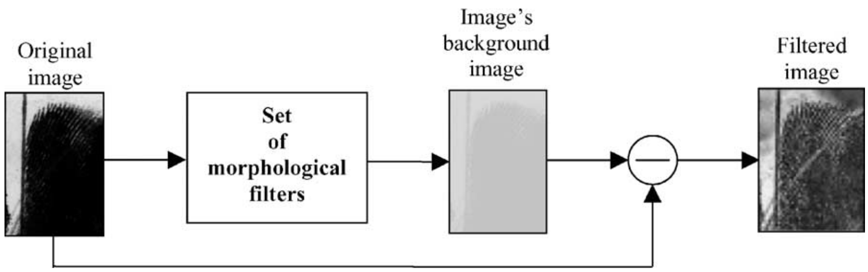



Fig. 1. Scheme of background noise reduction filtering.

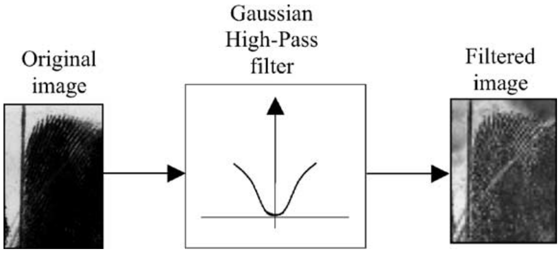



Fig. 2. Scheme of Gaussian high-pass filtering.

variations in contrast, leaving most of the image unchanged. If the window size is 1, the hysteresis process will have no effect at all. The output will be identical to the input. Conversely, with a large window size, most of the contrast variation in the image will be filtered out, leaving only areas of large contrast change. If the window size spans the range of all contrast intensities in the image, the hysteresis output will simply be flat, producing an image of only one grayscale intensity equal to the midpoint of the window size.

One way to preserve and enhance the small contrast variations in an image is to subtract the output of the hysteresis processing from the original data. Since the hysteresis output removes small variations but preserves large variations, subtracting the hysteresis output from the original image effectively reduces the large variations, leaving the small variations in the image.

The difference between the original image data and the hysteresis data is almost exclusively composed of small variations in contrast from pixel to pixel. Hysteresis processing removes these small variations, so subtracting the hysteresis output from the original data retrieves this information. Therefore, DHP is the result of performing the hysteresis-then-subtraction process on two copies of the original data, using a different window size (contrast window) for each process, and subtracting one result from the other. This allows the simultaneous suppression of one range of contrast variation while highlighting another range. This provides maximum flexibility in emphasizing the contrast variation of interest.

## 3. Results and discussion

The above explained techniques were combined in the following ways to obtain three different groups of processed images:

- Method 1: Filtering by background noise reduction and then Gauss-high-pass.
- Method 2: Filtering by DHP technique.
- Method 3: Filtering by background noise reduction, Gauss-high-pass and DHP technique.

Fig. 3 shows two different fingerprint subimages processed by the three enhancing methods previously mentioned. The first sample (sample 1) is very inky. The second one (sample 2) shows a fingerprint taken a long time post mortem. Fingerprints are partially showed to preserve the subject's identity.

In order to evaluate these results, two fingerprint Experts were asked to extract as many fingerprint details as possible of original images and processed ones with M1, M2 and M3 enhancing methods. A total of 80 fingerprint images were

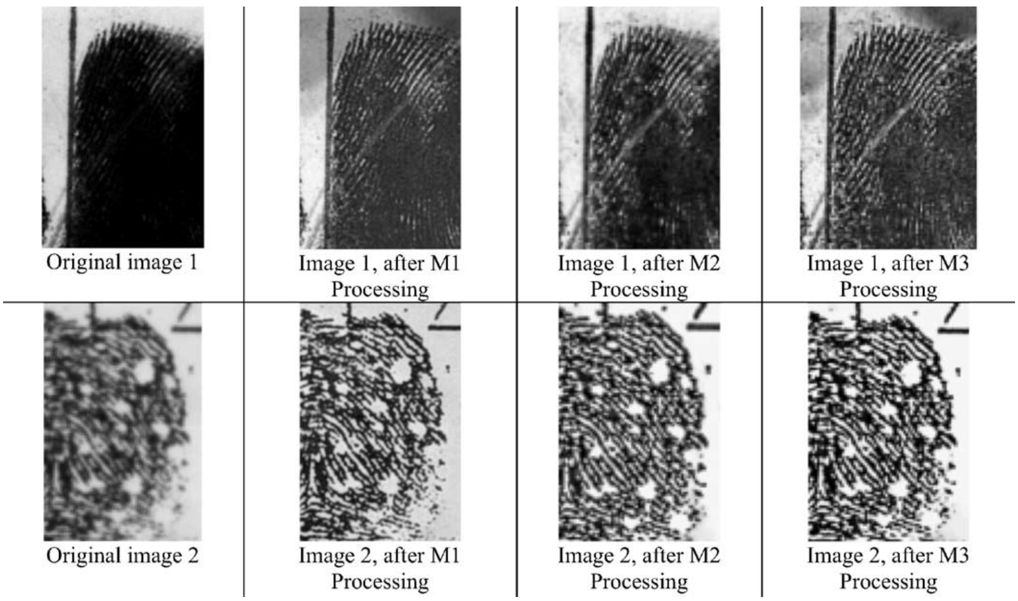
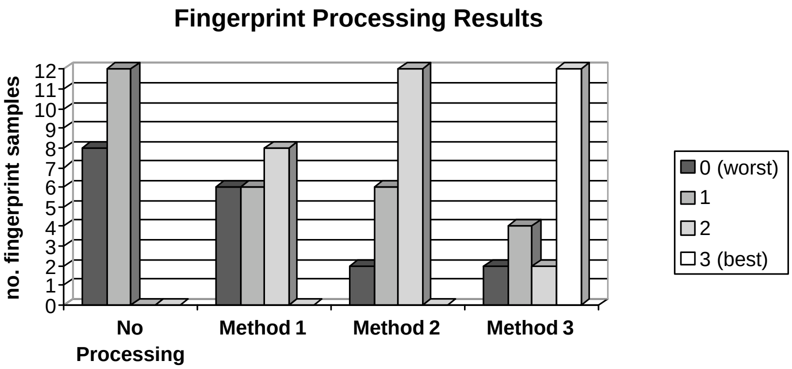



Fig. 3. Samples of enhancement results.




Scheme 1. Resume of results obtained by the fingerprint experts.

analyzed and the experts' observations were registered in order to contrast the suitability of each method. To quantify these opinions the following specific scale was developed, where the bigger number represents better processing result:

0—only the morphology's fingerprint could be observed.
1—the fingerprint classification type could not be observed.
2—above and only some minutiae points could be observed.
3—above and a good percentage of minutiae points could be observed.

The results obtained by both experts were compared and proved to be identical. Scheme 1 summarizes the results obtained, where it is possible to observe the performance of each processing method. The original fingerprints without enhancement revealed poor or null information (taller black bar) while best results (taller white bar) were obtained by combining the three techniques (M3 processing). In some fingerprints no significative improvement could be observed because of their very bad original conditions.

## 4. Conclusions

A fingerprint enhancement method, applicable to various kind of imperfections, which can improve the clarity of ridge and valley structures, by reducing the background noise first and then applying a contrast-improvement algorithm, has been developed.

The DHP algorithm applied after conditioning the fingerprint images by background noise reduction and high-Gauss filtering allows extracting and highlighting desired levels of contrast inside of the digital images. This capability can be used to improve and emphasize certain aspects of visual information. After a careful adjustment of the filter parameters the results proved be satisfactory in a wide range of cases uncovering prominent features in most fingerprints. This fact allows to save image processing time and facilitate the expert's analysis. These techniques can be applied not only to fingerprints, but also to other questioned documents [12–14].

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