TECHNICAL NOTE

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Computer Enhancement of Evidence Through Background Noise Suppression

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ABSTRACT: The use of computers to enhance evidence began more than twenty years ago [*1*] and first came to the authors' attention in 1977 [*2,3*], although significant success was achieved through image processing as early as 1974. Today, affordable software packages containing many programs are available. These programs may occasionally be used to advantage on weak or obstructed evidence [*4,5*]. Various terms have been used to describe these procedures, including "computer enhancement" and "image processing." An accurate description of these procedures as used by the authors would be "the optimization of signal to noise ratio." This signal optimization is achieved largely as a result of two factors. First, the digitization of the image affords the operator far greater control over each component of the image than is possible with a photographic (analogue) image. Second, the computer has the ability to discriminate between 256 separate values of gray, from black (0) to white (255), in contrast to approximately 32 separate values perceived by the human eye. Programs of immediate utility, comprising but a small part of the software package, will be described and illustrated.

KEYWORDS: forensic science, digitization, computer, noise suppression, subtraction

Equipment

All functions described herein were effected on a system integrated by Hunter & Associates, consisting of the following:

286 IBM compatible with math coprocessor
PC Vision-Plus RS 170 Capture Board
Hunter GIS Overlay Control Unit
Hewlett Packard ScanJet IIc Colour Scanner

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Monochrome Menu Display Monitor
Sony RGB Image Display Monitor
Sony Mavigraph BW and Colour Video Printer
Polaroid Freeze-Frame Plus Printer
Philips CCD Video Camera
Panasonic VHS Video Cassette Recorder
Media-Cybernetics Imagepro II Software

The most commonly used and valuable application of this computer system is, in the authors' opinion, background suppression. Conventional solutions to this common problem are often limited to photographic procedures such as lighting, contrast and filtration techniques.

Whatever the procedure employed, be it chemical, photographic or electronic, the analyst should be aware of factors vital to an accurate assessment of the method or methods used.

1) No development, enhancement or photographic technique can add or create information not already present.

2) An increase in signal-to-noise ratio need not be huge to have a significant effect on the conviction of the analyst viewing an evidence image. For example, if a number of characteristics in a fingerprint are obscured by background pattern, even a very slight suppression of that interference may allow the analyst to solidify his opinion, be it positive or negative.

3) There is a direct relationship between the skill and experience of the analyst, and the corresponding results. None of the conventional photographic methods of recording evidence are "user friendly." Rather, they are user dependent like the computer procedures described herein and should be recognized as such. This recognition may save the analyst from a premature and inaccurate assessment of the procedures being used.

4) Tangential to (3), it is imperative that an analyst have the knowledge and experience to select the specific procedures that will deal most effectively with any problems confronted, and also to recognize those instances where no computer procedures will be used successfully.

Fast Fourier Transform

The first technique in the Imagepro software to be used successfully by the authors is fast Fourier transform (FFT) [*6*]. This is a complex and intensive mathematical function which transforms the digitized image to a power spectrum (Fig. 1). In this power spectrum, repetitive patterns such as parallel lines or dots are manifested as bright spots or lines. These entities may be suppressed in the power spectrum by using the "spike cut" mode. When the modified power spectrum is transformed back to the digital image, the interfering pattern is either diminished or eliminated.

Conversely, continuous frequencies can be enhanced by the application of the "spike boost" FFT filter. Fingerprint ridges appear on the power spectrum also as bright spots, although not generally as bright or sharp as the spikes corresponding to uniform repetition. When the spike boost is applied correctly to these spikes related to ridge detail, the conversion back to image may reveal directional strengthening of the ridges. As with all image enhancement, the ability and experience of the user has a direct effect on the resulting image.

Case 1

A piece of fiber-reinforced tape was used to secure a bomb in a tool box. The tape was removed from recovered pieces of the tool box and processed in gentian violet. It

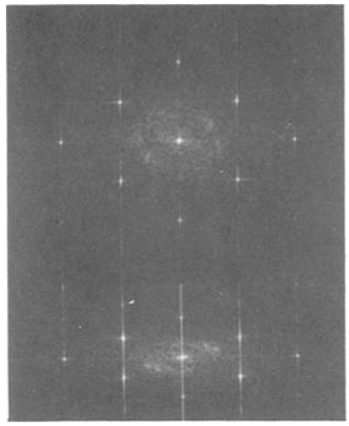

FIG. 1—*Power spectrum of captured image.*

was noted that the solution, in addition to developing fingerprint impressions on the adhesive side of the tape, the chemical had stained the longitudinal fibers in the tape, causing serious interference in the ridge detail (Fig. 2*A*). The FFT "spike cut" function was applied to the image and the interference from the stained fibers was significantly reduced, clearly revealing ridge characteristics not previously seen (Fig. 2*B*).

Case 2

An equipment manual seized in a major narcotics investigation was processed in ninhydrin, revealing a faint fingerprint that was obscured by a mechanical screen dot pattern (Fig. 3*A*). At this stage the impression was deemed to be unsuitable for comparison. Sections of the image containing ridge detail were subjected to FFT "spike cut" and a power spectrum was produced (Fig. 1). Noise entities were removed by using "spike cut" mode and the edited power spectrum was retransformed (Fig. 3*B*). A significant gain in clear detail was apparent, and the suspect was identified.

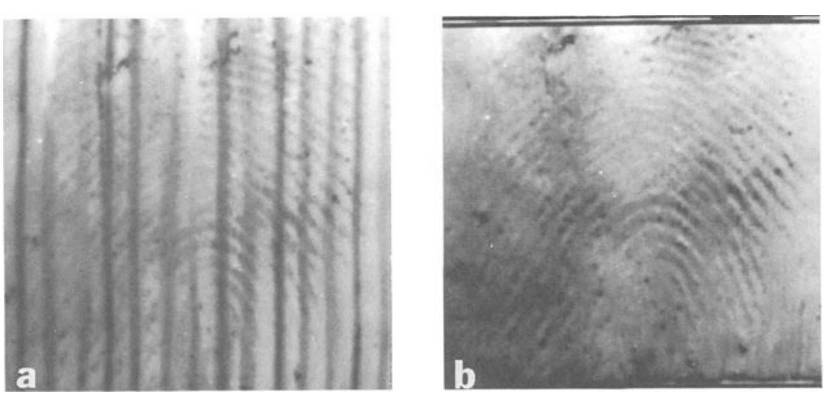

FIG. 2—*Case 1*—A) *Image of fingerprint disrupted by fibers in tape.* B) *Image of fingerprint after noise removal by FFT.*

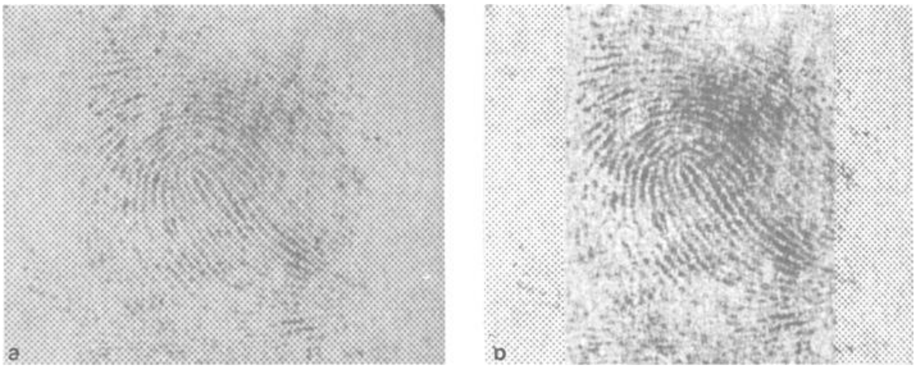

FIG. 3—*Case 2*—A) *Image of ninhydrin fingerprint disrupted by dot pattern from printing process.* B) *Image of fingerprint after FFT noise reduction.*

Case 3

A fingerprint was developed from the skin of a homicide victim using the iodine and silver plate technique. The resulting print reveals ridge detail that is difficult to read. Capture of this image was performed on a scanner (see equipment) from a photograph of the impression on the silver plate (Fig. 4*A*). The FFT spike boost was performed on the ridges, in addition to contrast and brightness changes. Finally, a sharpening filter was applied. The resulting image does not reveal detail not visible in the original image, however, the detail is more clearly visible and the count between ridge characteristics is more easily made (Fig. 4*B*).

The effectiveness of this procedure depends on several factors, not the least of which is the degree of complexity of the repetitive background pattern. The more uniform the interference is in size, direction, frequency and pixel value, the more specific (and more easily removed) will be the resultant entity in the power spectrum.

Another factor is the skill of the technician in correct interpretation of the power spectrum, both signal and noise entities. Finally, the technician must be able to use the ''spike cut'' editing mode to remove only noise entities.

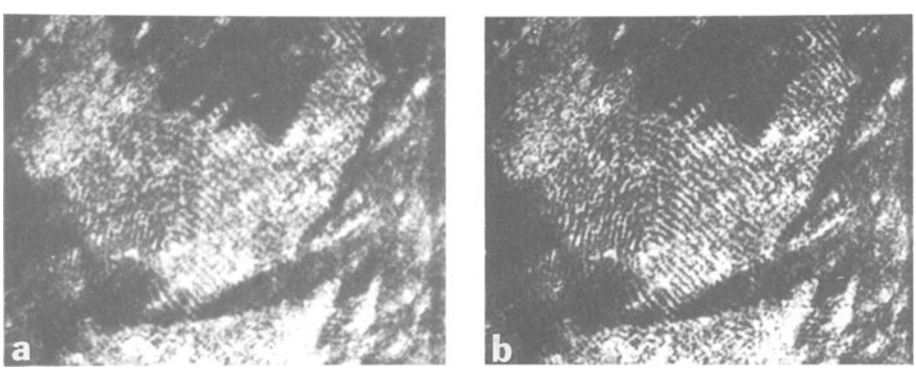

FIG. 4—*Case 3*—A) *Image of fingerprint developed on silver plate from skin of murder victim.* B) *Image of Fingerprint after FFT processing.*

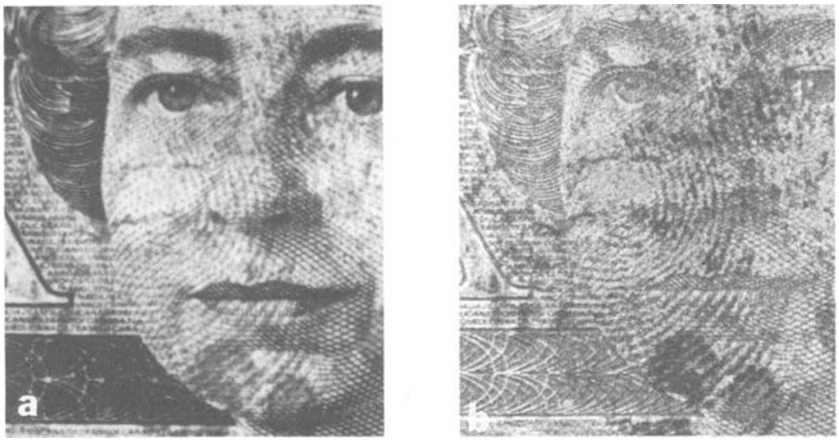

FIG. 5—A) *Image of ninhydrin-developed fingerprint on currency.* B) *image of fingerprint after background subtraction by filtration.*

Subtraction

Another approach to the suppression of background noise in a forensic image is use of the subtraction function. An image of the desirable element (fingerprint) is captured, along with the noise (background). Next, an image of only the background is captured, in exact registration with the first image. The two images are then subtracted, one from the other, pixel by pixel. In theory, the resultant image should contain only information present in the first image because detail common to both images would have been completely cancelled out in the subtraction process. In actual practice on the system previously described, this does not occur exactly as theoretically expected. Factors preventing the actual subtraction from duplicating the theoretical one may include lighting/voltage fluctuation and a degree of hardware limitation. Although the subtracted image is not, in the authors' opinion, as absolute as the theory would suggest, a significant and valuable suppression of the background can still be realized.

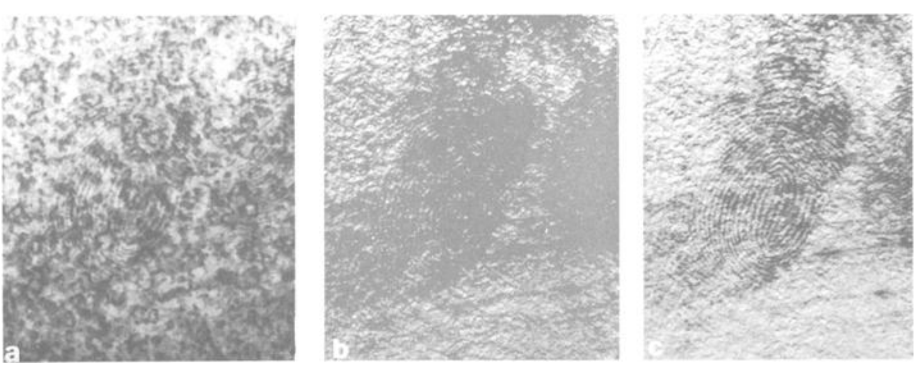

FIG. 6—A) *Image of obstructed powder impression on tile background.* B) *Result of subtraction without histogram adjustment.* C) *Result of subtraction after histogram adjustment.*

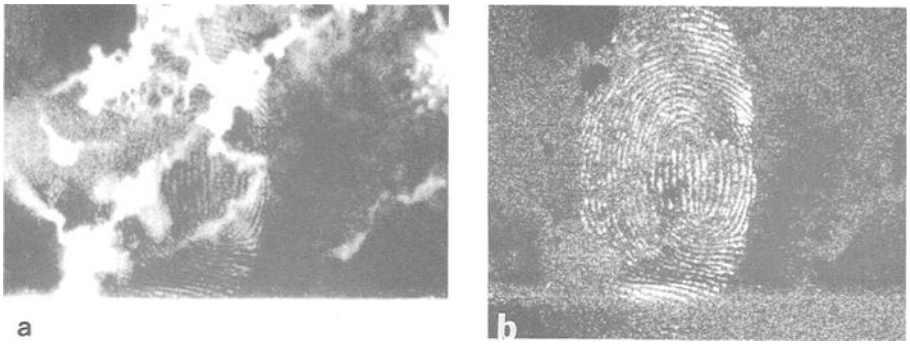

FIG. 7—A) *Image of fingerprint on tile obstructed by background.* B) *Image of fingerprint after histogram adjustment and subtraction by erasure.*

There are three approaches to image subtraction explored here. The advantages and limitations of each will be discussed in turn.

Predevelopment Capture of Background

If the background image is captured prior to the development of the evidence, the most complete and successful subtraction will be effected. However, in the authors' opinion, this procedure is limited in practical application. It would be extremely time-intensive, if not impossible, to anticipate development of evidence by capturing images of potential background on all suitable exhibits received for processing. Also, the exact registration of the two images to be subtracted would pose a major problem if the exhibit has been removed and processed between the capture of the first and second images. For these reasons, subtraction by pre-development capture is not recommended at this time.

Signal Filtration

If the desirable element in an image is of a color such as Ruhemann's Purple (ninhydrin process), a filtration/subtraction may be used to advantage. The image of a ninhydrin-developed fingerprint was captured as strongly as possible (Fig. 5*A*). Next, a second image was captured using a #33 Kodak Wratten filter without moving the exhibit, thereby insuring exact registration. This image displayed a greatly reduced, almost erased fingerprint. When the second image was subtracted from the first (Fig. 5*B*), a clear net gain in signal-to-noise ratio was realized. One drawback to this procedure is that if all or part of the background interference is significantly altered by the filter used, it will also be strengthened along with the desirable element.

If a simple subtraction of image "B" from image "A" (Fig. 6*A*) is performed, an undesirable compaction of the gray tones in the subtracted image "C" routinely occurs (Fig. 6*B*). A pixel with a gray value of 50 in image "A" and 50 in image "B" will result in a pixel value of 0 in image "C" (subtracted image). Pixel values of 0 or near 0 will therefore replace the subtracted value. A more satisfactory subtraction with greater yield of usable detail can usually be obtained by performing a positive histogram slide of approximately 30 index values on image "A" before subtracting image "B." This will result in the subtracted background being replaced by a mid-gray tone which is a more desirable matrix (Fig. 6*C*).

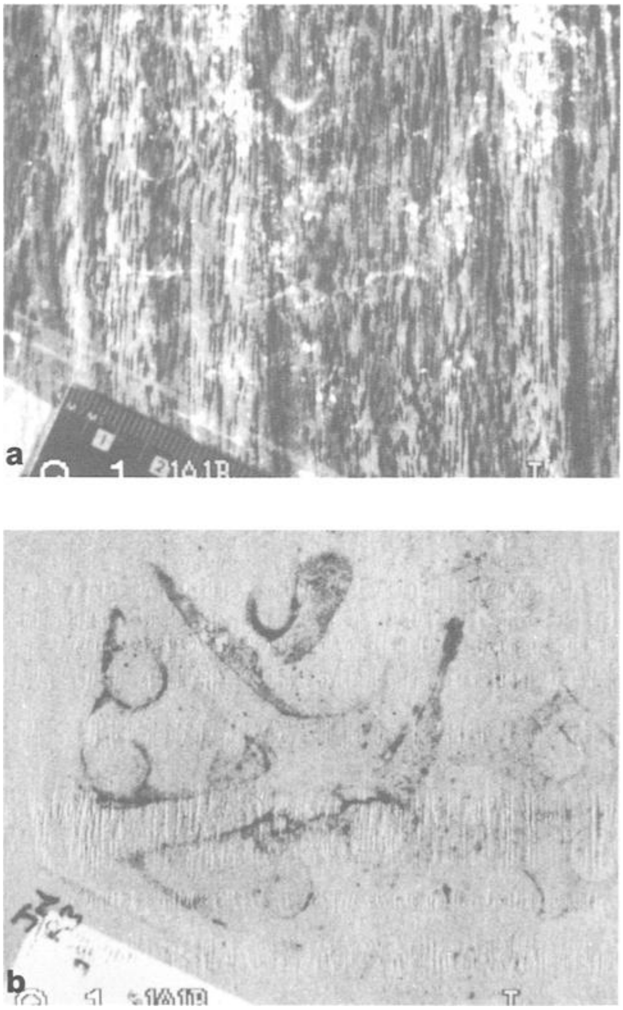

FIG. 8—A) *Image of footwear impression on woodgrain surface.* B) *Footwear impression after subtraction.*

Subtraction by filtration, although not as complete as predevelopment image capture, can effectively suppress background interference in some cases and is much easier and faster to perform. It is also non-destructive.

Signal Erasure

The last subtraction method explored is signal erasure. First, as in the filtration method, the image of the fingerprint was captured (Fig. 7*A*). Next, while the exhibit is retained securely in position to preserve registration, the fingerprint is erased and the remaining background image is captured. A positive histogram slide was performed (as described previously) and image "B" was subtracted from image "A" (Fig. 7*B*). This procedure may produce better results than filtration, but is much more invasive and should be

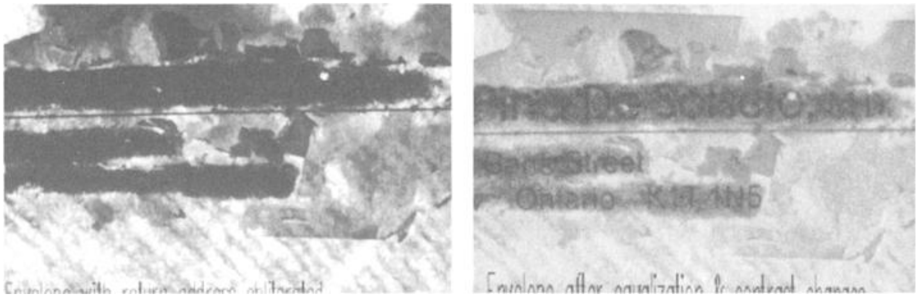

FIG. 9—A) *Return address obliterated by black magic marker.* B) *Return address after capture with a #88A infrared filter and histogram equalization.*

considered as a final alternative to extract useful evidence from an image, after all possible conventional methods have failed. Also every attempt should be made to preserve the evidence. First, it is recommended that an optimum photograph of the evidence be obtained prior to erasure. Next, if the subject is suitable, filtration subtraction should be attempted before erasure. If the evidence is in powder or dust, a lift may be carefully taken after the capture of image "A," before the erasure, and the capture of image "B." If the print is recorded in blood, the erasure step and acquisition of a sample swab may be one and the same.

Case 4

A footwear impression was developed in powder on an arborite countertop during the investigation of a homicide. The impression was photographed, lifted, developed again with powder, and lifted again. The exhibit was then submitted for computer enhancement (Fig. 8*A*). The countertop was subjected to signal erasure subtraction, using the positive histogram slide procedure previously described. The resulting image (Fig. 8*B*) allowed confirmation of the tread pattern and brand, and awaits comparison with suspect footwear, should any be submitted.

This case example illustrates graphically two features of the signal erasure subtraction procedure. First, as an electronic lifting device, this technique is extremely sensitive in recording threshold detail. Second, an extremely obstructive and irregular background can be eliminated as a factor.

The erasure of ninhydrin fingerprints can be easily accomplished with a mild household bleach solution (1 cc bleach to 40 cc water). Blood can best be removed in the conventional method to obtain a sample for laboratory submission. Dust and powder impressions have been most cleanly removed with ethyl alcohol.

It should be noted that the procedures described herein are intended as general ones and that modifications will be required to suit specific problems encountered in obtaining clear evidence images. The following steps, however, will serve as guides for both filtration and subtraction procedures.

Filtration

1) Capture image "A" (evidence plus background)
2) Capture image "B" (evidence suppressed by filter)
3) Slide histogram of "A" 25-30 index values higher
4) Subtract "B" from modified "A"

Signal Erasure

1) Capture image "A" (evidence plus background)
2) Erase evidence and all development medium
3) Capture image "B" (background)
4) Slide histogram of "A" 25-30 index values higher
5) Subtract "B" from modified "A"

Before attempting signal erasure on exhibits it is strongly recommended that practice erasures be conducted on sample exhibits to gain facility and confidence in the technique. Although signal erasure is both invasive and irreversible, forensic procedures which result in the alteration or destruction of the sample are certainly not new, and their use is justified by the potential acquisition of evidence not otherwise obtainable.

Histogram Equalization

This function allows the user to alter the dynamic range and contrast of an image [5]. It is of greatest utility in extracting information from an image or partial image with a compressed dynamic range that may be concealing important information. This unreadable image area may occur at any point in the range of index values 0 to 255 (light, mid-range or dark). The user selects one of five curves (bell, linear, cube, log and exponential) as a basis for redistribution of the existing index values. The curve chosen will depend on the nature of the image compression.

Case 5

An envelope related to a theft occurrence was found to bear a return address obliterated by black magic marker (Fig. 9*A*). Standard noninvasive methods of revealing obliterated information, including laser luminescence, proved unsuccessful. Infrared video examination revealed some of the underlying detail, but not enough to ascertain the hidden printing. The image of the obliterated area was captured with the CCD camera (infrared sensitive) using a Kodak #88A Wratten filter. Although some of the underlying information was made visible by this capture, there was still insufficient clear detail to read the return address. By applying a histogram equalization (Bell) to the image, however, the information can now be read (Fig. 9*B*).

The investigators were able to conclude that the envelope used was, in fact, retrieved from garbage, and that the individual whose address appears in this example was in no way involved in this occurrence.

Conclusions

1) Subtraction by filtration and signal erasure may increase signal-to-noise ratio in evidence images.

2) Application to Fast Fourier Transform may also be used in appropriate cases to maximize this ratio.

3) Correct assessment of each situation for its suitability is vital.

4) Histogram Equalization is an effective method of adjusting contrast in images to obtain maximum information.

5) Results obtained by using these procedures will be commensurate with the training, skill and experience of the user.

6) Overhigh expectations should be anticipated and avoided. Applications of other components of the software package and extensions of the programs discussed herein are currently under study and will be reviewed in a future paper.

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References

[1] Watling, W. J., "Where is Forensic Digital Image Enhancement Today?", presented at the International Association for Identification Conference, 1989, Pensacola, Florida.
[2] Corbett, F., "Digital Image Enhancement of the Hearst Bank Robbery Film," presented at the SPIE Technical Symposium East, 1977, Reston, Virginia.
[3] Corbett, F., "The Kennedy Assassination Film Analysis," presented at the SPIE Technical Symposium East, 1977, Reston, Virginia.
[4] German, E. R., "Electronic Latent Print Detection: A 1985 Update," presented at the International Association for Identification Conference, 1985, Savannah, Georgia.
[5] German, E. R., "Analog Digital Imaging Processing of Latent Fingerprints" in *Advances in Fingerprint Technology*, H. Lee and R. Gaensslen, Eds., Elsevier Press, New York, NY, 1991, pp. 193–210.
[6] Kaymaz, E. and Mitra, S. "A Novel Approach to Fourier Spectral Enhancement of Laser-luminescent Fingerprint Images," *Journal of Forensic Sciences*, JFSCA, Vol. 38, No. 3, May 1993, pp. 530–541.