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# Section 5

## *Guidelines for Image Processing*

**Previously called *"Recommendations and Guidelines for the Use of Digital Image Processing in the Criminal Justice System"***

### *Objective*

The purpose of this document is to provide guidelines for the use of digital image processing in the criminal justice system. The objective is to ensure the production of quality forensic imagery for use as evidence in a court of law. This document includes brief descriptions of advantages, disadvantages, and potential limitations of each major process.

### *SWGIT Position on Image Processing*

Traditional photography and its associated image processes have been used in legal matters since 1839[1]. Many of the same processes developed for traditional photography have equivalent counterparts in digital image processing. All of the techniques used in digital image processing have their roots in traditional photography and/or mathematics. This historical precedent helped digital image processing become established and accepted in forensic science.

It is the position of the Scientific Working Group on Imaging Technology (SWGIT) that any changes to an image made through image processing are acceptable in forensic applications provided the following criteria are met:

- The original image is preserved.
- Processing steps are documented when appropriate (see SWGIT document "*Best Practices for Documenting Image Enhancement*") in a manner sufficient to permit a comparably trained person to understand the steps taken, the techniques used, and to extract comparable information from the image.
- The end result is presented as a processed or working copy of the image.
- The recommendations of this document are followed.

### *Introduction*

Processed images are used for many purposes by the forensic science community. They can yield information not readily apparent in the original image, which can assist an expert in drawing a conclusion that might not otherwise be reached.

[1] Photographic Evidence, 2nd Edition, Charles C. Scott, West Publishing Company, St. Paul, MN. 1969, Vol.1, page 2.

This document addresses image processing and related legal considerations in the following three categories:

- Image enhancement
- Image restoration
- Image compression

When using image processing techniques, use caution to avoid the introduction of artifacts that add misleading information to the image or the loss of image detail that could lead to an erroneous interpretation. Any image processing should be applied only to a working copy of the image.

## *Image Enhancement*

Image enhancement is any process intended to improve the visual appearance of an image. Some of the processes below have a direct counterpart in the conventional silver-based photographic laboratory. Others can be accomplished only through digital processing.

*Brightness adjustment* is used when the image is too bright or too dark. If the image is made too bright, there is a risk of loss of detail in light areas. If the image is made too dark, there is a risk of loss of detail in the dark areas.

*Contrast adjustment* is used when the image lacks sufficient contrast. If the image contrast is increased too much, there is a risk of loss of detail in both light and dark areas.

*Cropping* is used to remove that portion of the image that is outside the area of interest.

*Dodging and burning* have the same effect as brightness adjustment but are used in localized areas.

*Color processing* includes color space transformations, pseudo coloring, and hue and saturation adjustments. These techniques can be used to modify the color characteristics of objects within an image.

***Caution: Application of these techniques can compromise the color fidelity of the image.***

*Linear filtering* techniques (see Figure 1) include sharpening, deblurring, edge enhancement, and deconvolution. They are used to increase the contrast of small detail in an image. If a low degree of enhancement is used, the image will remain an accurate representation of the scene. If a high degree of enhancement is used, the image may no longer be an accurate representation of the overall scene, though still may be useful as an adjunct for interpretation of small details.

***Caution: A high degree of enhancement can also increase the visibility of***

***existing noise and artifacts; examples of noise include film grain, snow appearing on a TV screen, or random color dots.***

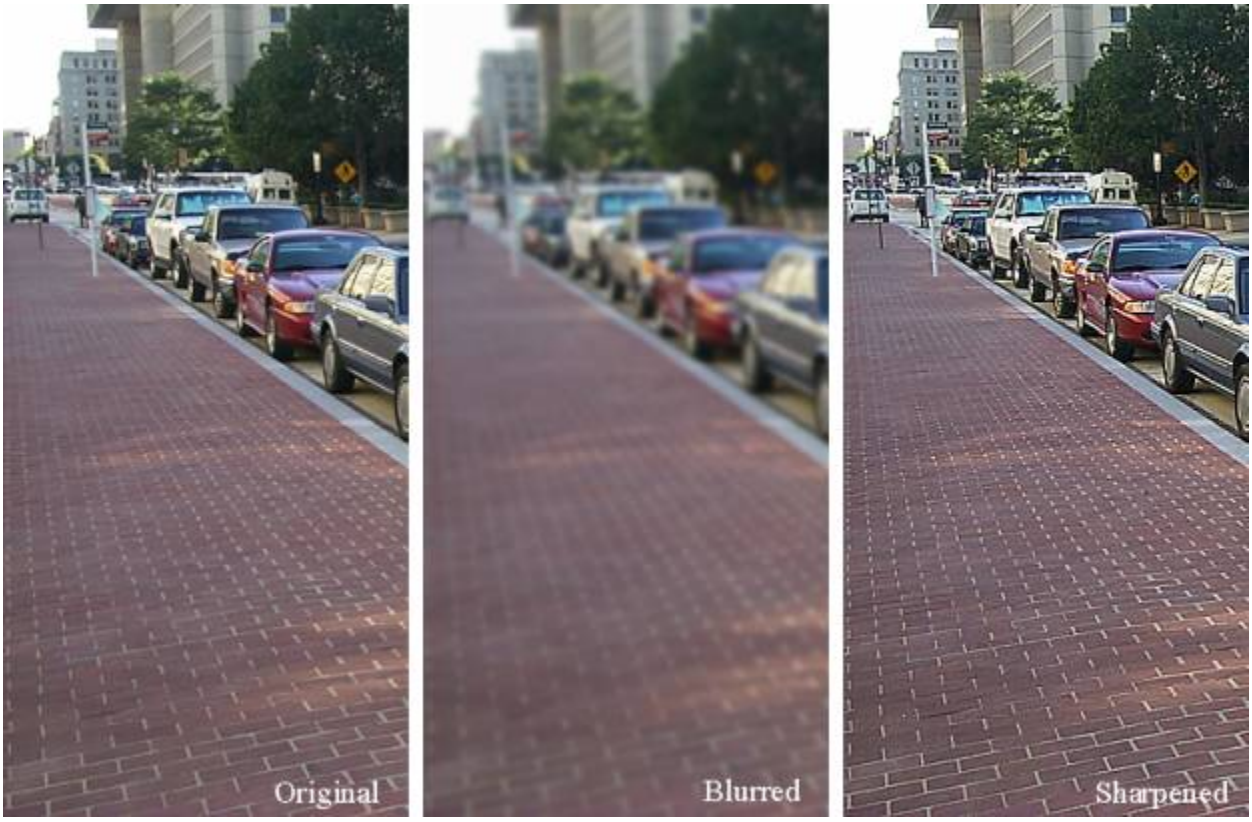


**Figure 1. This example illustrates the effects of linear filtering. Left: original image; Middle: blurred image; Right: sharpened image.**

*Nonlinear contrast adjustments* include gamma correction, grayscale transformation, and the use of curves and/or look-up tables. These are an extension of traditional photographic sensitometric techniques and are used to adjust the contrast in selected brightness ranges within the image.

A nonlinear contrast adjustment can be used to bring out details in the shadow areas of an image without affecting the highlight areas.

***Caution: A severe adjustment can cause loss of detail, color reversal, and/or the introduction of artifacts, see Figure 2 on the next page.***


**Figure 2. This example shows nonlinear contrast adjustments. Left: original image; Middle: enhancement of shadow and highlight areas, at the expense of midrange tones; Right: enhancement of midrange tones, at the expense of shadow and highlight areas.**

*Pattern noise reduction* filters identify repeating patterns in the image and allow the user to selectively remove them. This type of filter can be used to remove patterns such as fabric weaves, window screens, security patterns, and halftone dots.

***Caution: Overuse of this technique can cause selective removal of relevant image detail.***

*Random noise reduction* techniques include such filters as low pass filtering, Gaussian blurring, median filtering and despeckling. They are used to reduce the contrast of small detail in the image in order to suppress random noise.

***Caution: Overuse of this technique can cause loss of relevant detail.***

## *Image Restoration*

Image restoration is any process applied to an image that has been degraded by a known cause (e.g., defocus or motion blur) to partially or totally remove the effects of that degradation.

Limitations are imposed on this technique by any noise in the image and by the fact that information that has been totally lost cannot be replaced. Often partial restoration can be successful even when total restoration is impossible.

***Restoration Techniques***

*Blur removal* is a filtering technique designed to partially or completely remove an image blur imposed by a known cause. It differs from the image enhancement filtering processes because the blur removal filter is designed specifically for the process that blurred the particular image under examination. Examples include defocus and motion blur, since these blurring phenomena can be described mathematically. Thus, a specific filter can be designed to compensate for each blur. The degree to which a blur can be successfully removed is limited by noise in the image, the accuracy with which the actual blurring process can be described mathematically, and the fact that information has been totally lost and cannot be replaced. Often partial deblurring can be successful even when total deblurring is impossible.

*Grayscale linearization* is the adjustment of brightness relationships among the objects in a scene. The purpose of grayscale linearization is to render faithfully the different brightness values in the scene. For example, a monochrome test target having known gray values can be placed in the scene prior to recording the image. Then a grayscale transformation (nonlinear contrast stretch) can be designed to place the different gray values on the test target in their proper relationship. It is commonly assumed that the other objects in the scene will be put in their proper brightness relationship as well. Improper grayscale linearization can render brightness values inaccurately so that objects may appear brighter or darker than they actually appeared when the image was recorded.

*Color balancing* is the extension of grayscale linearization to a color image. It is the adjustment of the color components of an image. The purpose of color balancing is to render the colors in the scene faithfully. For example, a color test target having known colors can be placed in the scene prior to recording the image. Then a grayscale transformation (nonlinear contrast stretch) can be designed for each color channel (red, green, and blue) in order to place the different colors on the test target in their proper relationship. It is commonly assumed that the color of other objects in the scene will be rendered accurately as well. Improper color balance can render colors inaccurately, causing objects to appear to have the wrong color.

*Warping*, unlike other image restoration processes, changes the spatial relationships among the objects in an image. It is analogous to printing a photograph on a rubber sheet, then stretching the sheet in different directions and then tacking it down. Warping can be used, for example, to remove perspective from an image or to "unroll" a poster that was wrapped around a pole. Used improperly, it can distort the natural appearance of the objects in a scene.

*Geometric restoration* is the removal of geometric distortion from an image. Its purpose is to restore the proper spatial relationships among the objects in the scene. It can be used for the removal of geometric distortion, such as that introduced by a curved mirror or a fish-eye lens. It differs from image warping in that the geometric transformation is designed specifically for the process that distorted the particular image under examination. The degree to which geometric distortion can be successfully restored is limited by the accuracy with which the actual distortion process can be described mathematically and the fact that information that has been totally lost (e.g.,

hidden behind another object or obscured from the camera) cannot be replaced. Often, partial geometric restoration can be successful even when exact geometric restoration is impossible.

## *Image Compression*

Digital images produce a large amount of data to be stored. Image compression techniques reduce the storage requirements by making image data files smaller.

### *Compression Processes*

*Lossless compression* reduces file size by removing redundant information. Because the redundant information can be retrieved in order to display the image, lossless compression results in no loss of information. Lossless compression does not alter the content of an image when it is decompressed.

*Lossy compression* achieves greater reduction in file size by removing both redundant and irrelevant information. Because the irrelevant information (as determined by the compression algorithm) cannot be retrieved upon reconstruction of an image for display, compression results in some loss of image content as well as the introduction of artifacts. The degradation occurs each time the image is saved in a lossy file format. Higher compression ratios result in the loss of more information. Normally the degree of compression can be specified. Depending upon the application, lossy compression may render an image less useful.

The Joint Photographic Experts Group developed an image compression standard known as jpeg. This compression algorithm is applied to the image in 8-pixel by 8-pixel blocks. Normally, it is used as a lossy compression scheme where the degree of compression can be specified prior to storing the image. However, jpeg can also be used as a lossless compression scheme. At high compression ratios, jpeg could remove important image detail and introduce blocking artifacts as the block boundaries become visible (see Figure 3*)*. Jpeg is but one of many compression algorithms.

***Caution: Compression should be used with care to avoid material degradation of the image. Additionally, the compression settings used by one camera or software program may not be the same as the compression settings used by another camera or software program.***

**Figure 3. Left: original image; Middle: the result of JPEG compression (compression ratio = 15:1); Right: the result of edge enhancement after compression.**

### *Use of Compression*

Many digital cameras store images using jpeg compression, so that some compression is unavoidable. Some digital cameras are capable of storing images in an uncompressed form. The degree of compression should be set low enough that important image content is not lost or obscured by artifacts.

In instances where the primary or original image is already compressed, it should not be further compressed using lossy compression processes; additional data will be lost. Sources of compressed primary images may include electronic booking photographs, some types of digital camera images, and images downloaded from the internet or email. The file format is not an indicator of the compression history for an image. For example, a .tif file may have been previously compressed in a lossy file format (.jpg).

Be aware that the end use of any image may change over time, and the use of lossy compression may become problematic. When an image was compressed, documentation may be necessary in a court of law where there may be a challenge that lossy compression might have introduced artifacts or that relevant information was lost.

***Caution: Images intended for analysis should not be compressed using a lossy process.***

## Frequently Asked Questions (FAQ)

**Question:** What type of image must not be subjected to the following: image enhancement, compression, or restoration techniques?
**Answer:** A primary or original image.
**Discussion:** Because a primary or original image represents the first instance where the image is recorded onto any media, or it is an accurate and complete replica of the primary image, it must not be altered or modified.

**Question:** In a legal setting, what types of images are discoverable?
**Answer:** All images may be discoverable.
**Discussion:** In cases where images are processed, both the original and the processed image, along with associated documentation, may be discoverable.

**Question:** Who is responsible for testifying about a processed image?
**Answer:** The person who performed the processing or a person skilled in and knowledgeable about the processing that was used.
**Discussion:** The person who performed the processing is best qualified to testify about the technique(s) used. However, there may be occasions where the court will require the assistance of additional subject-matter experts. For issues relating to compression, the person who performed the compression can testify about the settings used to compress an image. Questions concerning the actual compression process should be referred to individuals who possess sufficient technical expertise to explain the specific process.

**Question:** Are there legal ramifications associated with the software used for image processing?
**Answer:** Yes.
**Discussion:** Some considerations may include:

- Have the particular functions within the software been accepted by the scientific community?
- Does the software perform as the manufacturer purports?
- Does the software have "plug-ins" that are produced by another manufacturer?
- Is the process repeatable and reliable?
- For image restoration, has the degradation process been accurately modeled?

**Question**: Where does image processing take place: in the field or in a controlled environment?
**Answer**: Both.
**Discussion**: Whereas most image processing takes place in a controlled environment, some image processing, such as image compression, may take place in the field. Image creation itself within a digital camera involves a significant degree of image processing and many modern digital cameras contain significant image processing software that can be controlled by the user.

**Question**: Who performs image processing?
**Answer**: Photographers, analysts, and technicians.
**Discussion**: The person performing the processing must be properly trained. See SWGIT document *"Guidelines and Recommendations for Training in Imaging Technologies in the Criminal Justice System"* and SWGIT/SWGDE document *"Guidelines and Recommendations for Training in Digital and Multimedia Evidence".*

**Question**: What are file management processes?
**Answer**: File management processes are the capture, storage, indexing, retrieval, and archiving of image files.
**Discussion**: Agencies and organizations should establish file management procedures for managing image files for use at a later date.

**Question**: Does image processing change images?
**Answer**: Yes.
**Discussion**: The purpose of image processing is to change the images in a controlled, predictable, and repeatable manner. Image processing does not mean that the original image is overwritten during the process. Forensic image processing should only be performed on working images. See SWGIT document *"Best Practices for Documenting Image Enhancement".*

**Question:** Is it necessary to document the step(s) used to produce a processed image?
**Answer:** Yes.
**Discussion:** The degree to which procedures used in image processing should be documented will depend on the intended end use of the image. Furthermore, the nature of such documentation will depend on the procedures used. See SWGIT document *"Best Practices for Documenting Image Enhancement".*

## *Guidelines for Digital Image Processing Standard Operating Procedures*

The purpose of image processing procedures is to apply processing techniques intended to enhance, restore, and/or compress digital images. Standard operating procedures should be developed and followed. The appendix is a sample standard operating procedure. See also SWGDE/SWGIT document "*Recommended Guidelines for Developing Standard Operating Procedures*".

Equipment

The agency should address the following minimum hardware and software equipment requirements.

Hardware:

- Input/capture device
- Image processing systems
- Output devices
- Storage/archive

Software:

- Image management
- Image processing

**Procedures**
Agencies should establish specific step-by-step procedures for image processing according to agency requirements using SWGIT guidelines. These procedures should address the following as a minimum:

- Capture
- Processing
- Storage/archive
- Image management
- Security
- Output

**Calibration**
If necessary, agencies should develop calibration procedures specific to their needs.

**Calculations**
If necessary, agencies should develop calculation procedures specific to their needs.

**Limitations**
Agencies should take into consideration agency-specific budget, equipment, management, and accrediting agency requirements.

**Safety**
Agencies should develop safety procedures specific to their needs.

**References**
Agencies should maintain its agency-specific documentation, manufacturers' manuals, and SWGIT guidelines.

**Training**
Agencies should document procedures to ensure sufficient training to afford competence and proficiency with applicable image processing. Refer to the SWGIT "*Guidelines and Recommendations for Training in Imaging Technologies in the Criminal Justice System*" and "*SWGDE/SWGIT Guidelines and Recommendations for Training in Digital and Multimedia Evidence*".

# Appendix

## SAMPLE Standard Operating Procedures for Latent Print Digital Imaging

Latent Print Units
Laboratory Division

### 1. Purpose

**1.1** This document sets forth Latent Print Units (LPU) specific procedures for latent print digital imaging.

### 2. Changes and Review

**2.1** The Section Chief and Unit Chiefs are the only persons who may authorize changes to this document.

**2.2** The appropriate LPU personnel who handle evidence which may be digitally processed must review the LPU Standard Operating Procedure for Latent Print Digital Imaging (SOP-LPDI).

### 3. Responsibilities

**3.1** The Section Chief, Unit Chiefs, Team Supervisors, and Program Managers are responsible for ensuring that LPU personnel adhere to the evidence-handling procedures stated in the LPU Evidence Control Policy.

**3.2** LPU personnel are required to handle evidence slated for latent print digital imaging in accordance with the procedures set forth in the LPU Evidence Control Policy.

### 4. Sending Evidence to the Latent Photography and Digital Imaging Group

**4.1** LPU Specialists will determine if latent print digital image processing for enhancement purposes is needed after the appropriate silver based photographic procedures have been performed.

**4.1.1** Specialists will initiate a separate Latent Print Digital Imaging Requisition form (LPDIR) for each item of evidence and will ensure all information is accurate.

**4.1.2** Specialists will submit the form and appropriately sealed evidence to the Latent Photography and Digital Imaging Group (LPDIG).

### 5. Evidence Receiving in Latent Photography and Digital Imaging Group

**5.1** LPDIG personnel will ensure that the LPDIR form and the evidence are submitted properly, and will sign for receipt.

### 6. Digital Image Capture

**6.1** Upon receipt, the LPDIG Supervisor or designee will assign the submission to a photographer trained in digital imaging.

**6.1.1** The assigned photographer will initiate a LPU Latent Print Digital Imaging Processing form (LPDIP).

**6.1.2** The assigned photographer will use a digital image capture device to record the image of the latent print(s) in question and save the original image for each latent print using the file name structure to be defined.

**6.1.3** The photographer will record the file name(s) assigned to the image(s) on a separate LPDIP form for each latent print. If the evidence is no longer needed, it will be stored in the evidence storage facilities in the LPDIG.

## 7. Digital Image Processing

**7.1** The LPDIG Supervisor and Technology Development and Support Group(TDSG) Supervisors or respective designees will determine which specialist or photographer should perform the processing.

**7.2** If the case specialist is not a digitally trained specialist, the specialist/photographer assigned will then contact the case specialist to arrange a time for the processing, so that the case specialist can be present when the processing is performed.

**7.3** All processing steps will be recorded in the order they are performed either on a LPDIP form or within the computer program, if the program has that capability.

**7.4** Once the case specialist is satisfied that the best possible image has been achieved, the image will be saved with a second file name assigned and recorded on the LPDIP form.

**7.5** The case specialist will receive the original of the LPDIR and LPDIP forms along with all appropriate computer printouts for case documentation. A hard copy of both the original and processed images will also be provided for comparison purposes.

**7.5.1** If no improvement results from this process and no images will be utilized by the case specialist, the original forms will be returned to the case specialist for case documentation, and a notation on the worksheet must be made that reflects the results of this effort. No image files will be stored when no improvement results.

## 8. Storage and Archiving of Images

**8.1** All images, both original and processed, will be stored temporarily on the hard drive of the imaging station until the examination(s) is completed.

**8.2** A backup copy of the images will be created weekly by the LPDIG Supervisor or designee and maintained in a locked cabinet within the LPU LPDIG until the examination(s) is completed.

**8.3** Once the examination(s) is completed, the LPDIG Supervisor or designee will record the resultant images on two Digital Video Disks (DVD's) or Compact Disks (CD's) along with any associated case information. One DVD/CD will be designated a working copy and kept with the digital imaging equipment in a locked cabinet. The second DVD/CD will be designated as archival and kept in a locked cabinet within the TDSG.

**8.3.1** The LPDIG Supervisor or designee will enter the appropriate DVD/CD serial numbers on both the LPDIR and LPDIP forms, return the originals to the case specialist, and file the duplicate copy of the LPDIP form within the locked cabinet along with the archival DVD/CD.

**8.3.2** The DVD/CD's will be filed by the engraved serial number in numerical order in the above-mentioned cabinets. A database will be maintained by the LPDIG Supervisor.