Scientific Working Group on Digital Evidence

SWGDE Image Processing Guidelines

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SWGDE Image Processing Guidelines

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1. Objective

(Note: This document is an update to the version previously released as SWGIT Section 5 – Guidelines for Image Processing.)

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

2. SWGDE 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 and/or mathematics. This historical precedent helped digital image processing become established and accepted in forensic science.

It is the position of the SWGDE 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 and processes are performed on a working copy.
- Processing steps are documented, see *SWGIT Section 11 Best Practices for Documenting Image Enhancement* [2], 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 of the image.
- The recommendations of this document are followed.

3. 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.

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, which could lead to an erroneous interpretation. Any image processing should be applied only to a working copy of the image.

4. 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.***

High Dynamic Range (HDR) is a set of techniques used in photography to reproduce a greater dynamic range than is possible with standard digital imaging or photographic techniques. The aim is to reproduce what the human eye naturally sees. Most cameras cannot produce this natively. It is accomplished by taking multiple images of the same scene at different exposure values and combining them in a photo imaging program. Application of this technique overlays the same visual image captured with slightly different exposure. See **Figure 1** for examples of HDR photography.

- ***Caution: Using too large a range of images can produce an image that has a greater visual range than the human eye normally sees.***

Credit: Ft. Worth Police Dept.

Figure 1. Examples of HDR photography.

Linear filtering techniques, see **Figure 2**, 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.***

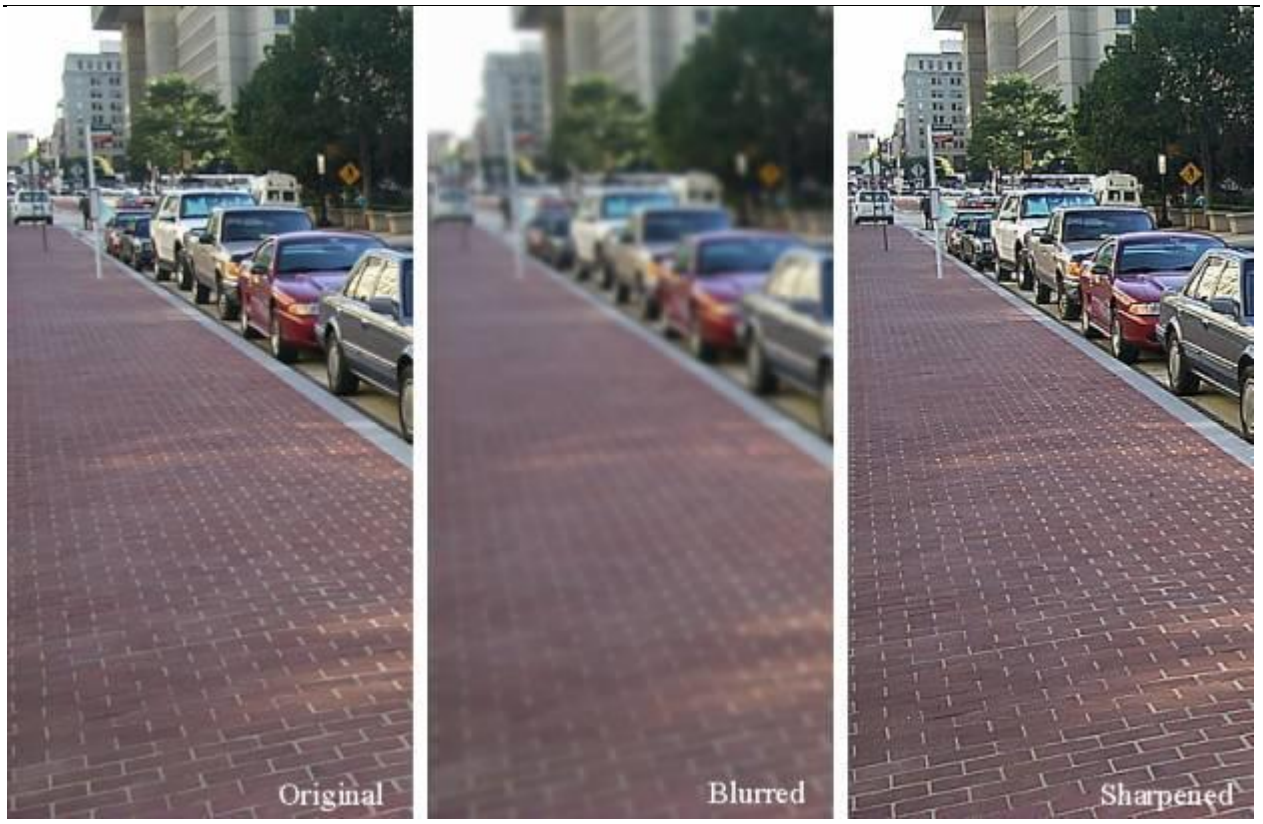

Figure 2. This example illustrates the effects of linear filtering. Left: original image; Middle: blurred image; Right: sharpened image.

Nonlinear contrast adjustments include gamma correction, grayscale transformation, and the use of curves and/or look-up tables. These are 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 3. *These adjustments can cause the image to be non-representative of the lighting conditions of the scene.***

Figure 3. 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.***

5. Image Restoration

Image restoration is any process applied to an image that has been degraded (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.

5.1 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 (i.e., 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.

6. 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; refer to *SWGIT Section 19 Issues Relating to Digital Image Compression and File Formats* [3].

6.1 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 4***)*. 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 4. Left: original image; Middle: the result of JPEG compression (compression ratio = 15:1); Right: the result of edge enhancement after compression.

6.2 Use of Compression

Many digital cameras store images using jpeg compression so that some compression is unavoidable when photographing using the jpg file format. 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.***

7. Frequently Asked Questions (FAQs)

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 Section 6 Guidelines and Recommendations for Training in Imaging Technologies in the Criminal*

Justice System [4] and *SWGDE/SWGIT Guidelines & Recommendations for Training in Digital & Multimedia Evidence* [5].

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 [2].

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 [2].

8. 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. This section is a sample standard operating procedure. See also *SWGDE Model Standard Operation Procedures for Computer Forensics* [6].

8.1 Equipment

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

- Hardware:
  - Input/capture device (e.g. digital cameras, scanners)
  - Image processing systems (e.g. computers with imaging software)
  - Output devices
  - Storage/archive
- Software:
  - Image management
  - Image processing

8.2 Procedures

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

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

8.3 Calibration

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

8.4 Limitations

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

8.5 Safety

Agencies should develop safety procedures specific to their needs.

8.6 References

Agencies should maintain its agency-specific documentation, manufacturers' manuals, and SWGDE guidelines.

8.7 Training

Agencies should document procedures to ensure sufficient training to afford competence and proficiency with applicable image processing, refer to [4] and [5].

9. References

[1] Charles C. Scott, *Photographic Evidence*, 2nd ed. St. Paul, MN: West Publishing Company, 1969, vol. 1.

[2] Scientific Working Group on Imaging Technology, "Section 11: Best Practices for Documenting Image Enhancement". [Online]. https://www.swgit.org/documents/Current%20Documents

[3] Scientific Working Group on Imaging Technology, "Section 19: Issues Relating to Digital Image Compression and File Formats". [Online]. https://www.swgit.org/documents/Current%20Documents

[4] Scientific Working Group on Imaging Technology, "Section 6: Guidelines and Recommendations for Training in Imaging Technologies in the Criminal Justice System". [Online]. https://www.swgit.org/documents/Current%20Documents

[5] Scientific Working Group on Digital Evidence and Scientific Working Group on Imaging Technology, "SWGDE/SWGIT Guidelines & Recommendations for Training in Digital & Multimedia Evidence". [Online]. https://www.swgde.org/documents/Current%20Documents

[6] Scientific Working Group on Digital Evidence, "SWGDE Model Standard Operation Procedures for Computer Forensics". [Online]. https://www.swgde.org/documents/Current%20Documents

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