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Standard Guide for Forensic Digital Image Processing[1]

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1. Scope

1.1 This guide provides digital image processing guidelines to ensure the production of quality forensic imagery for use as evidence in a court of law.

1.2 This guide briefly describes advantages, disadvantages, and potential limitations of each major process.

2. Referenced Documents

2.1 *ISO/IEC Standard:*[2]

ISO/IEC 10918-1:1994 Information technology—Digital compression and coding of continuous-tone still images: Requirements and guidelines (JPEG) (also published as CCITT Recommendation T.81 (1992))

2.2 *SWGIT Material:*[3]

SWGDE/SWGIT Glossary SWGDE and SWGIT Digital & Multimedia Evidence Glossary, updated June 8, 2012

3. Terminology

3.1 *Definitions:*

3.1.1 *artifact, n*—visual/aural aberration in an image, video, or audio recording resulting from a technical or operational limitation. **SWGDE/SWGIT Glossary**

3.1.1.1 *Discussion*—Examples include speckles in a scanned picture or "blocking" in images compressed using the JPEG standard.

3.1.2 *compression, n*—process of reducing the size of a data file (see *lossy compression* and *lossless compression*). **SWGDE/SWGIT Glossary**

3.1.3 *grayscale image, n*—continuous tone image that has only one component. **ISO/IEC 10918-1:1994**

3.1.4 *grayscale transformation, n*—operation that modifies a single channel or component of image data (for example, a single color).

3.1.5 *image, n*—imitation or representation of a person or thing, drawn, painted, photographed, and so forth. **SWGDE/SWGIT Glossary**

3.1.6 *image enhancement, n*—any process intended to improve the visual appearance of an image or specific features within an image. **SWGDE/SWGIT Glossary**

3.1.7 *lossless, adv*—descriptive term for encoding and decoding processes and procedures in which the output of the decoding procedure(s) is identical to the input to the encoding procedure(s). **ISO/IEC 10918-1:1994**

3.1.8 *lossless coding, n*—mode of operation that refers to any one of the coding processes defined in this guide in which all of the procedures are lossless. **ISO/IEC 10918-1:1994**

3.1.9 *lossless compression, n*—compression in which no data are lost and all data can be retrieved in their original form. **SWGDE/SWGIT Glossary**

3.1.10 *lossy, adv*—descriptive term for encoding and decoding processes that are not lossless. **ISO/IEC 10918-1:1994**

3.1.11 *lossy compression, n*—compression in which data are lost and cannot be retrieved in their original form. **SWGDE/SWGIT Glossary**

3.1.12 *noise, n*—variations or disturbances in brightness or color information in an image that do not arise from the scene. **SWGDE/SWGIT Glossary**

3.1.12.1 *Discussion*—Sources of noise include film grain, electronic variations in the input device sensor and circuitry, and stray electromagnetic fields in the signal pathway. It frequently refers to visible artifacts in an image.

3.1.13 *original image, n*—accurate and complete replica of the primary image, irrespective of media. **SWGDE/SWGIT Glossary**

3.1.13.1 *Discussion*—For film and analog video, the primary image is the original image.

3.1.14 *primary image, n*—first instance in which an image is recorded onto any media that is a separate, identifiable object. **SWGDE/SWGIT Glossary**

3.1.14.1 *Discussion*—Examples include a digital image recorded on a flash card or a digital image downloaded from the internet.

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[2] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[3] Available from Scientific Working Group on Imaging Technology (SWGIT), http://www.swgit.org.

3.1.15 *restoration, n*—any process applied to an image that has been degraded by a known cause (for example, defocus or motion blur) to remove partially or totally the effects of that degradation. **SWGDE/SWGIT Glossary**

4. Summary of Practice

4.1 The original image shall be preserved. Any image processing should be applied only to a working copy of the image.

4.2 Any changes made through image processing shall meet the following criteria:

4.2.1 Processing steps are documented in a manner sufficient to permit a comparably trained person to understand the steps taken, the techniques used, and extract comparable information from the image; and

4.2.2 The end result is presented as a processed or working copy of the image.

4.3 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.

5. Significance and Use

5.1 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.

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

5.2.1 Image enhancement,

5.2.2 Image restoration, and

5.2.3 Image compression.

6. Image Enhancement

6.1 Image enhancement is any process intended to improve the visual appearance of an image.

6.1.1 Use brightness adjustment 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.

6.1.2 Use color processing to modify the color characteristics of objects within an image. This includes color space transformations, pseudocoloring, and hue and saturation adjustments.

6.1.2.1 Application of these techniques can compromise the color fidelity of the image.

6.1.3 Use contrast adjustment 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.

6.1.4 Use cropping to remove that portion of the image that is outside the area of interest.

6.1.5 Use dodging and burning to adjust brightness in localized areas.

6.1.6 Use linear filtering techniques (see Fig. 1) to increase the contrast of small detail in an image. These include sharpening, blur removal, edge enhancement, and deconvolution. 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

FIG. 1 This Example Illustrates the Effects of Linear Filtering—Left: Original Image, Middle: Blurred Image, and Right: Sharpened Image

accurate representation of the overall scene, though it still may be useful as an adjunct for interpretation of small details.

6.1.6.1 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 television screen, or random color dots.

6.1.7 Use nonlinear contrast adjustments to adjust the contrast in selected brightness ranges within the image. These include gamma correction, grayscale transformation, and the use of curves or look-up tables, or both.

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

6.1.7.2 A severe adjustment can cause loss of detail, color reversal, or the introduction of artifacts, or a combination thereof. (See Fig. 2.)

6.1.8 Use pattern noise reduction filters to identify repeating patterns in an image and selectively remove them. This type of filter can be used to remove patterns such as fabric weaves, window screens, security patterns, and halftone dots.

6.1.8.1 Overuse of this technique will remove material image detail.

6.1.9 Use random noise reduction techniques to reduce the contrast of small detail in the image to suppress random noise. These include such filters as low-pass filtering, Gaussian blurring, median filtering, and speckle removing.

6.1.9.1 Overuse of this technique will remove material image detail.

6.1.10 Use warping to change 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.

6.1.10.1 Used improperly, warping can distort the natural appearance of the objects in a scene.

7. Image Restoration

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

7.2 Information that has been totally lost in the image during the original imaging process cannot be replaced through restoration. However, partial restoration can be successful even when total restoration is impossible.

7.3 *Restoration Techniques:*

7.3.1 Use blur removal to remove partially or completely an image blur imposed by a known cause.

7.3.1.1 Blur removal 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 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 that has been totally lost cannot be

FIG. 2 This Example Shows Nonlinear Contrast Adjustments—Left: Original Image, Middle: Enhancement of Shadow and Highlight Areas at the Expense of Midrange Tones, and Right: Enhancement of Midrange Tones at the Expense of Shadow and Highlight Areas

replaced. Often partial blur removal can be successful even when total blur removal is impossible.

7.3.2 Use color balancing to render the colors in the scene more accurately. Color balancing is the extension of grayscale linearization to a color image and the adjustment of the color components of an image. For example, a color test target having known colors can be placed in the scene before recording the image. Then a grayscale transformation (nonlinear contrast stretch) can be designed for each color channel (red, green, and blue) to place the different colors on the test target in their proper relationship. This should reproduce the other objects in the scene in their proper relationship.

7.3.2.1 Improper color balance can render colors inaccurately causing objects to appear to have the wrong color.

7.3.3 Use grayscale linearization to render faithfully the different brightness values in the scene. This adjusts the brightness relationships among the objects in a scene. For example, a monochrome test target having known gray values can be placed in the scene before 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. This should put the other objects in the scene in their proper brightness relationship as well.

7.3.3.1 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.

7.3.4 Use geometric restoration to restore the proper spatial relationships among the objects in the scene. This restoration removes geometric distortion from an image. It can be used for the removal of geometric distortion, such as that introduced by a curved mirror or a fish-eye lens.

7.3.4.1 Geometric restoration differs from image warping in that the geometric transformation is designed specifically for the process that distorted the particular image under examination.

7.3.4.2 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 (for example, 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.

8. Image Compression

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

8.2 *Compression Processes:*

8.2.1 Lossless compression reduces file size by removing redundant information. Because the redundant information can be retrieved 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.

8.2.2 Lossy compression achieves greater reduction in file size by removing both redundant information and data deemed expendable by the compression algorithm. Because the expendable data 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.

8.2.2.1 Degradation occurs each time the image is compressed using a lossy process, such as saving to a compressed format.

8.2.2.2 Higher compression ratios result in the loss of more information. Normally, the degree of compression can be specified.

8.2.2.3 Depending upon the application, lossy compression may render an image less useful.

8.2.3 The Joint Photographic Experts Group developed an image compression standard known as JPEG (ISO/IEC 10918-1:1994). This compression algorithm is applied to the image in 8 by 8-pixel blocks. Normally, it is used as a lossy compression scheme in which the degree of compression can be specified before 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 Fig. 3). JPEG is but one of many compression algorithms.

8.2.3.1 Compression should be used with care to avoid material degradation of the image.

8.2.3.2 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.

8.3 *Use of Compression:*

8.3.1 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 material image content is not lost or obscured by artifacts.

8.3.2 In instances in which 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 Tagged Image File Format (TIFF[4]) file may have been previously compressed using a lossy algorithm (**1**).[5]

8.3.3 The material use of an image may change over time. Any compression used to save an image should be appropriate for the intended use at that time.

8.3.3.1 Images intended for laboratory analysis should not be compressed using a lossy process unless the resulting image still retains the relevant information as determined by the laboratory personnel conducting the analysis.

[4] TIFF is a trademark of Adobe Systems Incorporated.

[5] The boldface numbers in parentheses refer to a list of references at the end of this standard.

FIG. 3 Left: Original Image, Middle: the Result of JPEG Compression (Compression Ratio = 15:1), and Right: the Result of Edge Enhancement after Compression

9. Guidelines for Digital Image Processing Standard Operating Procedures

9.1 The purpose of image-processing procedures is to apply processing techniques intended to enhance, restore, or compress digital images, or a combination thereof. Standard operating procedures should be developed and followed. A sample standard operating procedure is included in the SWGIT document "Guidelines for Image Processing" (**2**). See also the SWGDE/SWGIT document, "Recommended Guidelines for Developing Standard Operating Procedures" (**3**).

9.2 *Equipment*—The laboratory standard operating procedure (SOP) should define minimum hardware and software equipment requirements including, but not limited to:

9.2.1 *Hardware:*

9.2.1.1 Input/capture device,

9.2.1.2 Image-processing systems,

9.2.1.3 Output devices, and

9.2.1.4 Storage/archive.

9.2.2 *Software:*

9.2.2.1 Image management, and

9.2.2.2 Image processing.

9.3 *Procedures*—Laboratories should establish specific step-by-step procedures for image processing according to published guidelines. These procedures should address the following as a minimum:

9.3.1 Capture,

9.3.2 Processing,

9.3.3 Storage and archiving,

9.3.4 Image management,

9.3.5 Data security, and

9.3.6 Output

9.4 *Calibration*—Laboratories should develop SOPs for calibrating all equipment that produces test results. These procedures should be consistent with the manufacturer's recommendations.

9.5 *Limitations*—Laboratories should document the limitations of their processes and equipment in their SOPs.

9.6 *Safety*—Laboratories should develop safety procedures specific to their needs.

9.7 *References*—Laboratories should maintain their laboratory specific documentation, manufacturers' manuals, and published guidelines.

9.8 *Training*—Laboratories should define the level of training necessary to perform the procedure. Refer to the SWGIT "Guidelines and Recommendations for Training in Imaging Technology in the Criminal Justice System" (**4**) and "SWGDE/SWGIT Guidelines and Recommendations for Training in Digital and Multimedia Evidence" (**5**).

10. Keywords

10.1 criminal justice system; digital image processing; image processing

APPENDIX

(Nonmandatory Information)

X1. SAMPLE STANDARD OPERATING PROCEDURES FOR LATENT PRINT DIGITAL IMAGING (LATENT PRINT UNITS LABORATORY DIVISION)

X1.1 Purpose

X1.1.1 This guide sets forth the Latent Print Units (LPU) specific procedures for latent print digital imaging.

X1.2 Changes and Review

X1.2.1 The section chief and unit chiefs are the only persons who may authorize changes to this guide.

X1.2.2 The appropriate LPU personnel who handle evidence that may be digitally processed shall review the LPU standard operating procedure for latent print digital imaging (SOP-LPDI).

X1.3 Responsibilities

X1.3.1 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.

X1.3.2 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.

X1.4 Sending Evidence to the Latent Photography and Digital Imaging Group (LPDIG)

X1.4.1 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.

X1.4.1.1 Specialists will initiate a separate latent print digital imaging requisition form (LPDIR) for each item of evidence and ensure all information is accurate.

X1.4.1.2 Specialists will submit the form and appropriately sealed evidence to the LPDIG.

X1.5 Evidence Receiving in LPDIG

X1.5.1 LPDIG personnel will ensure that the LPDIR form and evidence are submitted properly and will sign for the receipt.

X1.6 Digital Image Capture

X1.6.1 Upon receipt, the LPDIG supervisor or designee will assign the submission to a photographer trained in digital imaging.

X1.6.1.1 The assigned photographer will initiate a LPU latent print digital imaging processing form (LPDIP).

X1.6.1.2 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.

X1.6.1.3 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.

X1.7 Digital Image Processing

X1.7.1 The LPDIG supervisor and Technology Development and Support Group (TDSG) supervisors or respective designees will determine which specialist or photographer should perform the processing.

X1.7.2 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.

X1.7.3 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.

X1.7.4 Once the case specialist is satisfied that the best possible image has been produced, the image will be saved with a second file name assigned and recorded on the LPDIP form.

X1.7.5 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.

X1.7.5.1 If no improvement results from this process and no images will be used by the case specialist, the original forms will be returned to the case specialist for case documentation, and a notation on the worksheet shall be made that reflects the results of this effort. No image files will be stored when no improvement results.

X1.8 Storage and Archiving of Images

X1.8.1 All images, both original and processed, will be stored temporarily on the hard drive of the imaging station until the examination(s) is completed.

X1.8.2 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.

X1.8.3 Once the examination(s) is completed, the LPDIG supervisor or designee will record the resultant images on two digital video disks (DVDs) or compact disks (CDs) 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.

X1.8.3.1 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.

X1.8.3.2 The DVDs/CDs will be filed by the engraved serial number in numerical order in the cabinets in X1.8.3.1. A database will be maintained by the LPDIG supervisor.

REFERENCES

(1) TIFF Revision 6.0 Final—June 3, 1992, http://partners.adobe.com/public/developer/en/tiff/TIFF6.pdf.

(2) SWGIT Section 5: Guidelines for Image Processing, updated Jan. 15, 2010, Scientific Working Group on Imaging Technology, www.swgit.org.

(3) SWGDE/SWGIT Recommended Guidelines for Developing Standard Operating Procedures, Version 1.0, Nov. 15, 2004, Scientific Working Group on Digital Evidence/Scientific Working Group on Imaging Technology, www.swgit.org.

(4) SWGIT Section 6: Guidelines and Recommendations for Training in Imaging Technology in the Criminal Justice System, Version 1.3, June 11, 2010, Scientific Working Group on Imaging Technology, www.swgit.org.

(5) SWGDE/SWGIT Guidelines and Recommendations for Training in Digital and Multimedia Evidence, updated Jan. 15, 2010, Scientific Working Group on Digital Evidence/Scientific Working Group on Imaging Technology, www.swgit.org