SWGIT

Scientific Working Group
Imaging Technology

Section 12

Best Practices for Forensic Image Analysis

OBJECTIVE

The objective of this document is to provide personnel with guidance regarding practices appropriate when performing a variety of analytic tasks involving images, regardless of the knowledge domain that is the subject of analysis.

SWGIT POSITION ON FORENSIC IMAGE ANALYSIS

Forensic image analysis is a forensic science. It has been practiced since the early days of photography, dating at least to 1851 when Marcus A. Root conducted the first documented example of Forensic Image Authentication. Through microscopic examination, Root revealed that the color daguerrotype "process" promoted by Reverend Levi Hill was actually the product of hand coloring, not a breakthrough in photographic science (Davis, Photography, Brown & Benchmark, 1995). In addition to being an accepted scientific practice in the forensic community, image analysis is also recognized in other disciplines including medicine, intelligence, geology, astronomy, agriculture, and others.

INTRODUCTION

Forensic Image Analysis is the application of image science and domain expertise to interpret the content of an image and/or the image itself in legal matters. Major subdisciplines of Forensic Image Analysis with law enforcement applications include: Photogrammetry, Photographic Comparison, Content Analysis, and Image Authentication.

The process of Forensic Image Analysis can involve several different tasks, regardless of the type of image analysis performed. These tasks fall into three categories: Interpretation, Examination, and Technical Preparation. These tasks are described below. The general principles and procedures used in these tasks are the same regardless of the format or media in which the images are recorded. Therefore, in this document the word "image" refers to any image recorded on any media (e.g., film, electronic, magnetic, or optical media, etc.).

FORENSIC IMAGE ANALYSIS – GENERAL TASKS

Interpretation

Interpretation, as used here, is the application of specific subject matter expertise to draw conclusions about subjects or objects depicted in images. Examples include a podiatrist drawing conclusions about foot shape from an image, a shoeprint expert drawing conclusions about the provenance of a shoe, or a military expert drawing conclusions about force distribution from remote sensing data.

Examination

Examination is the application of image science expertise to the extraction of information from images, the characterization of image features, and the interpretation of image structure. Examples include watermark detection, steganalysis, extraction of Photo Response Non-Uniformity signature and image alteration evaluation, as well as the development of case-specific image exploration strategies. Image enhancement, image restoration, and other image processing activities intended to improve the visual appearance of features in an image are examination tasks.

Technical Preparation

Technical preparation is the performance of tasks such as preparation of evidence or images for examination, interpretation, or output. Note that there is a wide gamut of technical decision making within the various responsibilities covered by technical preparation actions. Some responsibilities may involve minimal technical decision making, such as feeding paper into a preset sheet fed scanner that has been previously calibrated. Some responsibilities may involve a great deal of technical decision making, such as determining appropriate color balance, sampling during acquisition, or output resolution.

Note: Interpretation, Examination, and Technical Preparation are tasks, not job descriptions or roles. An individual may perform part of one task or a combination of multiple tasks within the organizational structure of any given activity. Each of these tasks requires its own training and qualification.

FORENSIC IMAGE ANALYSIS – SPECIFIC AREAS OF ANALYSIS

Photogrammetry

"Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through the processes of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant energy and other phenomena." [from "The Manual of Photogrammetry, 4th Edition, 1980, ASPRS]. In forensic applications, photogrammetry (sometimes called "mensuration") most commonly is used to extract dimensional information from images, such as the height of subjects depicted in surveillance images and accident scene reconstruction. Other forensic photogrammetric applications include visibility and spectral analyses.

Figure 1 illustrates an example of a photogrammetric analysis conducted to determine the height of a subject depicted in a bank robbery surveillance photograph.

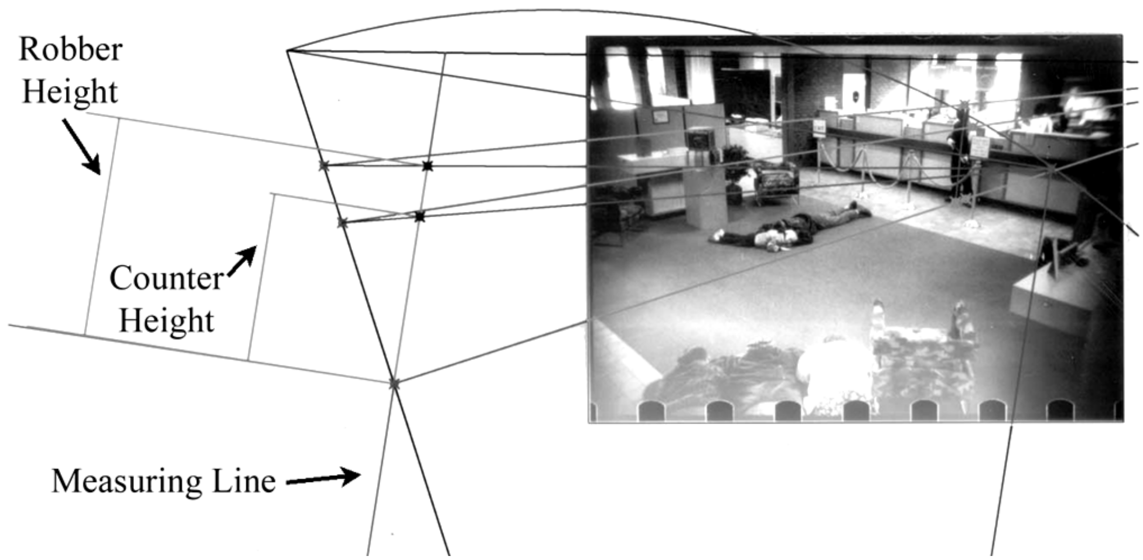

Figure 1.

Photographic Comparisons

Photographic comparison is an assessment of the correspondence between features in images and known objects for the purpose of rendering an expert opinion regarding identification or elimination (as opposed to a demonstrative exhibit). Examples of photographic comparisons include, but are not limited to:

- A facial comparison between an unknown subject depicted in a surveillance image with an identified suspect; (see www.FISWG.org for more information)
- The comparison of objects such as vehicles depicted in surveillance images with those recovered in an investigation;
- The comparison of a questioned image with a known camera to determine if the image was captured using that camera.

Photographic comparisons are frequently referred to as “side-by-side” comparisons since they usually involve a comparison of class and individualizing characteristics in imagery. The scientific basis and technical processes involved in photographic comparisons are comparable to those used in other forensic disciplines such as fingerprint analysis. ACE-V (Analysis, Comparison, Evaluation – Verification) is a common protocol used to perform photographic comparisions. Statistical analysis can be used as a component of the evaluation stage of ACE-V, but is not required.

Figure 2 illustrates demonstrative exhibits from a facial comparison exam, in which ACE-V was used to individualize the subject as the same person in both images.

Figure 2.

Figure 3 illustrates a demonstrative exhibit from a clothing comparison examination, in which ACE-V was used to individualize the camouflage jacket as the same one in both images.

Figure 3.

Content Analysis

Content analysis, within the context of forensic image analysis, is the drawing of conclusions about an image. Targets for content analysis include, but are not limited to:

- the subjects/objects within an image;
- the conditions under which, or the process by which, the image was captured or created;
- the physical aspects of the scene (e.g., lighting or composition); and/or
- the provenance of the image.

Examples include vehicle license plate number identification, patterned injury analysis, correlation of injuries inflicted in an image sequence with autopsy results, determination of the presence of computer-generated imagery in an alleged “snuff” film, and determination of the type of camera used to record a specific image.

Image Authentication

Image Authentication is verification that the information content of the analyzed material is an accurate rendition of the original data by some defined criteria. These criteria usually involve the interpretability of the data, and not simple format changes that do not alter the meaning or content of the data.
Examples include:

- Determining the degradation of a transmitted image;
- Determining whether a video is an original recording or an edited version;
- Evaluating the degree of information loss in an image saved using lossy compression.
- Determining whether an image contains feature-based modifications such as the addition or removal of elements in the image (e.g., adding bruises to a face).

BEST PRACTICES

The following are guidelines that describe the SWGIT recommended best practices for the performance of forensic image analysis.

Evidence Management

Agencies should have documented procedures for the handling, transportation, and storage of evidence. Agencies should have chain of custody procedures in place and should follow these procedures.

Quality Control and Quality Assurance

Quality control and quality assurance policies and procedures should be implemented and documented. Technical and Administrative peer reviews are integral components of quality control.

Security

There should be procedures in place to maintain the security of the working data, all notes, and other such analysis-related materials to provide the level of security and privacy needed by the organization. For example, archived case-related materials should be stored in a manner that limits access. The degree of access will be agency-specific.

Infrastructure

Agencies should have sufficient space, equipment and facilities to adequately support the required quality and volume of work.

Work Management

Because forensic image analysis is a labor-intensive process, an upper limit on caseload should be established for every category of tasks.

Documentation

The practitioner should have available documentation that describes and justifies the use of any method involved in the analysis. Such documentation can include peer-reviewed journal articles, scientific conference proceedings, reference books, internal white papers, or the results of empirical studies.

The application of analytic techniques in a given case should be recorded to the degree that a similarly trained professional would reach a comparable analytical conclusion.

Agencies should establish standards for information included in, and the format for, reporting results.

Training, Competency, and Proficiency

Practitioners of Image Analysis should follow SWGIT-SWGDE Guidelines and Recommendations for Training in Digital & Multimedia Evidence and SWGDE/SWGIT Proficiency Test Program Guidelines.

Analysts should have certification in their knowledge domain and associated forensic discipline, when such certification is appropriate and available. Note, however, that the mere existence of a certification program does not imply that it is necessary, sufficient, or appropriate.

Analysts should demonstrate competency in their discipline prior to being assigned unsupervised case work responsibilities. In addition, analysts should demonstrate proficiency and maintain continuing education activities. Agencies should document competency, proficiency and continuing education of each analyst.

The practitioner should demonstrate:

- understanding of the scope of work and how it will be applied in the forensic environment;
- subject matter knowledge and competence;
- working knowledge of the potential image processing and evaluation techniques;
- working knowledge of applications and tools utilized in the specific agency;
- working knowledge of SWGIT guidelines for capturing, storing, and processing of imagery, including issues relating to topics such as data integrity and compression artifacts;
- understanding of legal precedent for the use of specific image processing techniques;
- knowledge of the techniques necessary to document the conclusions.

Standard Operating Procedures (SOPs)

There should be Standard Operating Procedures (SOPs) for the tasks being performed. These SOPs should reflect the work flow and be general enough to permit flexibility for the required tasks.

Work Flow

The following describes a generalized sequence of actions involved in the analysis of an image and recommendations for their performance. The exact sequence will be agency specific.

1. Review of request for analysis.
    a. The agency must confirm that it performs the requested analysis.
    b. The agency must ensure the requestor has submitted all items needed to support the requested analysis or examination. Note: In some cases, it may be necessary for the agency to obtain additional items or information before an analysis can be completed.
    c. The agency must confirm that it has the necessary equipment, materials, and resources needed to conduct the requested analysis.
    d. The agency must assign the analysis request to the appropriate personnel.

2. Acquisition of imagery.

    This is the implementation of the acquisition strategy determined in the initial assessment. It produces the image for the steps that follow. Often, analysis or examination may be performed on objects directly or on analog images without the need for digitization. The primary or original image should be archived in a manner that permits verification. The image acquisition step is where the integrity of the primary or original data is initially established. Most often, subsequent steps are performed utilizing working copies, but in all cases, the integrity of the primary or original image(s) must be maintained.

a. If possible, the original or primary image, or a bit-for-bit duplicate, should be available for analysis.
b. Triage imagery
    i. The practitioner must determine if the submitted material is suitable for analysis.
    ii. The practitioner must determine if all of the submitted material, or only a subset of the material, is to be subjected to analysis.

3. Production of Working Copies.
Produce working copies of images to be subjected to analysis. This may require digitization from negatives, prints, or conversion from other media.

4. Processing of Images to be Analyzed.
(**Note:** Guidance relating to forensic image processing [FIP] and case-specific documentation requirements for FIP can be found in the following SWGIT documents: “Recommendations and Guidelines for the Use of Digital Image Processing in the Criminal Justice System” and “Best Practices for Documenting Image Enhancement”).

    a. Design an image processing strategy. This is the application of domain knowledge to choose which processes to apply to the image to extract the information necessary for drawing a conclusion. The strategy should be justifiable. No single processing strategy is appropriate for all cases. This should be reflected in the organizational SOPs.
    b. Identify the appropriate tools to implement the strategy. There should be some references/documentation that the selected tools are capable of implementing the strategy.
    c. Implement the designed image processing strategy.
    d. Assess results. Determine that the image processing strategy yielded results suitable for analysis.
        i. If the results are suitable for analysis, then proceed to the analysis (5). Otherwise, repeat process of designing an image processing strategy until suitable results are achieved.

    Note: Exploratory strategies that are not incorporated into the final work flow pathway need not be documented in case notes. Agencies may wish to document this fact in their SOPs.

5. Analyze processed data.
    a. Determine if criteria necessary for reaching a conclusion are present in the processed image.
        i. Specific criteria for reaching a conclusion should be identified and documented.
        ii. In some cases, the criteria will reflect the subjective experience of the practitioner. Such conclusions should be confirmed through appropriate technical review.
    b. Reach conclusion.

6. Report Conclusions.
    a. Some conclusions (e.g. photogrammetric analysis) can be reported in terms of statistical criteria. In contrast, many conclusions are derived from the observations of a trained examiner. The basis for, and uncertainty of, any conclusion should be reflected in the reporting.

    b. When a statistical basis for a conclusion can be made, the conclusion should be quantitatively reported. It may be possible to provide bounds on probabilities based on incomplete knowledge. See Appendix A.

    c. When statistical criteria do not exist, the conclusion should be reported in terms of the kind of features discerned. The ACE-V protocol is one way of doing this. Another way of doing this is to use a graded scale. An example of such a graded scale is provided in Appendix B.

    d. The report format and contents should follow agency standards.

Work Flow Examples

Photogrammetric Analysis Example

A local police agency asks the state crime lab to determine the height of the individual depicted robbing the convenience store in a surveillance video tape. The police have two suspects of different heights and would like the crime lab to determine if either can be excluded on this basis.

Following the workflow delineated above, the agency proceeds:

1. The agency reviews the request and:
    a. determines that they perform this type of analysis,
    b. determines that all necessary items to support the requested exam have been submitted,
    c. determines that they have the necessary equipment, materials, and resources needed to conduct the requested analysis, and
    d. they assign the analysis request to an analyst.

2. The analyst acquires the necessary imagery.
    a. The analyst observes that the videotape has no markings that would indicate that it is a copy, then verifies that it is an original using available video processing equipment.
    b. The practitioner reviews the video sequence of interest and locates images suitable for photogrammetric analysis.

3. The analyst digitizes still images from the analog video sequence for use in the analysis as working copies.

4. Standard image processing techniques such as brightness and contrast adjustments and deinterlacing are applied to the working images.

5. The analyst imports the images into a photogrammetric application and conducts an analysis. This analysis results in a calculated value for the robber's height, as well as a determination of the accuracy and precision of this result. The analyst compares these results with the reported heights of the two suspects and eliminates one of the suspects on this basis.

6. The analyst writes the report. Per the crime lab's SOPs, the report includes a review of the materials received, the request, the methods used, the results obtained, an estimate of accuracy and precision, the basis for the conclusion, and the conclusion.

Photographic Comparison Example

An FBI field office investigating a report of child abuse recovers a compact disc containing digital image files that appear to depict the suspect's left hand upon a victim. A second compact disc is received containing digital image files of a known suspect's left hand. An FBI image analysis unit is requested to perform a photographic comparison of the questioned and known hands to determine if the hands belong to the same individual.

Following the work flow described above, the unit proceeds:

1. The agency reviews the request and:
    a. determines that they perform this type of analysis,
    b. determines that all necessary items to support the requested exam have been submitted,
    c. determines that they have the necessary equipment, materials, and resources needed to conduct the requested analysis, and
    d. they assign the analysis request to an analyst.

2. The analyst acquires the necessary imagery.
    a. The analyst calls the investigating agency and determines that copies of the original images have been received. The authentication was performed by the investigating agency.
    b. The practitioner reviews the imagery and selects several images for further analysis.

3. The analyst makes copies of the selected imagery for use as working copies, and safely stores the received data.

4. Image processing techniques such as brightness and contrast adjustments, unsharp masking, and multi-pixel averaging are performed. The use of these techniques are documented per the unit's SOP.

5. The resulting images are analyzed and it is determined that compression artifacts present in the questioned images prevent unambiguous identification of individualizing features on the hand. The class characteristics of the questioned and known hands, however, are observed to be similar. Therefore, the analyst

concludes that similarities exist which allow the inclusion of the suspect, but do not permit the identification or elimination of the suspect.

6. The analyst writes the report. Per the unit's SOPs, the report includes a review of the materials received, the request, the methods used, the results obtained, the basis for the conclusion, and the conclusion.

Content Analysis Example

A four-year-old child is admitted to the hospital, complaining of fever. Emergency room (ER) physicians note a confluent red rash over the victim's trunk and groin. The child begins having seizures, stops breathing, and dies. Resuscitation efforts fail. The local physician signs the death certificate as "death due to scarlet fever." The coroner is not informed of the death, and the body is cremated. Three weeks after cremation, a family member makes the accusation that the child had been dipped in boiling water. The ER physician had taken digital snapshots of the rash as a teaching tool.

The county medical examiner's office is asked to evaluate the imagery to determine if the injuries are consistent with scarlatina or child abuse.

Following the work flow described above, the medical examiner's office proceeds:

1. The agency reviews the request and:
   a. determines that they perform this type of analysis,
   b. determines that all necessary items to support the requested exam have been submitted,
   c. determines that they have the necessary equipment, materials, and resources needed to conduct the requested analysis, and
   d. assigns the analysis request to a medical examiner (ME).

2. The ME acquires the necessary imagery.
   a. The ME calls the hospital and subpoenas the child's records.
   b. The ME confirms that the imagery is a copy of the digital snapshots taken by the ER doctor.
   c. The ME reviews the documents and imagery and selects several images for further analysis.

3. The ME makes working copies of the selected imagery, and safely stores the received data.

4. No image processing is required.

5. The selected images are analyzed and it is determined that the pattern of injury on the body, the location on the body, and the texture of the rash, is incompatible with immersion in boiling water. Examination of the medical records reveals a positive blood culture for *Streptococcus pyogenes*. In addition, a rapid test for influenza A was performed and was positive. Therefore, the ME concludes that the skin lesion was due to scarlatina resulting from a *S. pyogenes* superinfection secondary to influenza A.

6. The ME writes the report. Per the Medical Examiner's Office's SOPs, the reasoning behind the conclusions and the results are detailed.

APPENDIX A

Reporting Conclusions through Quantitative Means (Commentary and Example)

Classic photogrammetric evaluation is amenable to estimation of error, either through the propagation of error involved in the calculations or in comparison with fiducials that may be present in an image. The reader is referred to standard photogrammetric and numerical methods texts for the former. In many images that require measurement, there are objects of known dimension. These may be used to provide estimates of error. Both common kinds of error (imprecision and bias) should be estimated if possible, and if not possible, the limitations of the method should be mentioned in the final report.

Example: Evaluation of hostage photograph. A government agency has obtained a photograph of a middle-aged male hostage. They wish an estimate of the time since capture based on the assumption that the man has not been allowed to shave. The analyst is instructed to measure the hairs on the chin of the hostage and estimate the time since last shave. The hostage photograph is taken with the hostage holding a newspaper below his chin, and the date is estimated to be in mid-May. In addition, the victim is wearing a known brand shirt, with buttons of minimal manufactured tolerance. The button diameter is 12mm (+/- 0.0001 mm).

Photogrammetric measurement of 6 buttons reveals an average measured diameter of 12.01 mm (+/- 0.02 mm). Measurement of 100 hairs on the chin reveals an average length of 3.2 mm (+/- 0.3mm) for pigmented hairs and 7.2 mm (+/- 0.5 mm) for nonpigmented hairs.

The photogrammetric error is thus of an order of magnitude less than the error of the hair, and can be discounted. The published average growth rate for beard hair is 0.47mm/day for pigmented hair (+/- 0.2mm) and 1.12 mm/day for white hair. The May date allows negligible adjustment for seasonal hair growth variation (which may be up to 60%). White hair growth data is discarded because of great interpersonal variation.

The estimate of beard growth is thus 3.2/0.47 = 6.8 days, with an estimated error of sqrt[(0.3/3.2)*(0.3/3.2) + (0.2/.42)*(0.2/.42)]*6.8 or 3.3 days.

The estimate is thus that the hostage had been kept for 6.8 +/- 3.3 days, ignoring the (sizeable) seasonal variation and (possibly sizeable) nutritional effects. Both the error and the ignored sources of error are noted in the final report.

APPENDIX B
Reporting Conclusions Through the Use of a Graded Scale (Commentary and Example)

When a statistical basis for the conclusion can be made, the conclusion should be reported in terms of probability. When statistical criteria do not exist, the conclusion may be reported in terms of the kind of features discerned and their correspondence or disagreement. One way of doing this is through the use of a graded scale such as the following:

- Grade 0: Exclusion.
- Grade 1: Correspondence of class characteristics only.
- Grade 2: Correspondence of class characteristics and pseudorandom characteristics for which the underlying probability distribution is unknown.
- Grade 3: Correspondence of class characteristics and acquired/random characteristics which can be considered unique within a selected population.

It may be possible to provide bounds on probabilities based on incomplete knowledge. If the examiner decides to provide such a bound, then a statement of probabilities can be made as commentary, with explicit description of the underlying assumptions. For example, consider a piece of clothing with a given fabric pattern. An estimate of a certain percentage could be made that the cloth has a given orientation for one panel and another percentage for another panel. If the assumption is made (and stated), or if investigation of the manufacturing process allows determination that the orientations are independent, then it is possible to calculate a total probability by multiplying the individual probabilities. Thus, if panel A is at most 40% likely to have a given orientation, and panel B is at most 40% likely to have a given orientation, then an upper bound of 16% of the clothing thus made will have that particular combination of panel orientations. For the most part, however, these kinds of data are not available to investigators, and the limit of examination will be a grade-based conclusion.