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Standard Practice/Guide for Image Processing to Improve Automated Facial Recognition Search Performance

1. Scope.

    1.1 The purpose of this document is to provide facial examiner guidelines for processing a probe image in order to maximize the potential that an investigative lead will be included among the candidates returned following a facial recognition system (FRS) search.

2. Referenced Documents

    2.1 *ASTM Standards*:

        E2916 Terminology for Digital and Multimedia Evidence Examination[1]

        E2825 Standard Guide for Forensic Digital Image Processing

    2.2 Other Standards:

        ANSI/NIST- ITL-1-2011 Data Format for the Interchange of Fingerprint, Facial & Other Biometric Information[2]

3. Terminology

    3.1 *Definitions:* See ASTM E2916 Terminology for digital and multimedia evidence examination terms.

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[1] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@asstm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

[2] https://www.nist.gov/programs-projects/ansinist-itl-standard

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3.2 *Acronyms*

FR—Facial recognition

FRS—Facial Recognition Systems

3.3 *Lossy compression*—compression in which data are lost and cannot be retrieved in their original form

4. Summary of Guide

4.1 Scope
The scope of the image processing steps presented in this document are limited to the manual processing of images intended to be submitted as probe images for FRS searches. Internal image processing applied by the FRS and issues associated with still image extraction from video, scanning of printed imagery, and the use of forensic sketches, reconstructions, and composites are beyond the scope of this document.

5. Significance and Use

5.1 Introduction

Images that meet agreed upon international standards (such as ISO/IEC 19794-5: Face Image Data[3]) can normally be submitted to an FRS for searching with little or no operator intervention. Many FRS also include intrinsic mechanisms for correcting minor deviations in subject pose, image size or vendor specific adjustments to the image. Manual processing by a trained facial examiner may be beneficial for sub-optimal images (e.g. low resolution, heavily compressed or where the subject's pose, illumination, and/or expression are non-neutral). The processing techniques presented in this document may be applied over an entire image and/or in localized areas of an image.

The image processing topics presented in this document are not intended to override recommendations for maintaining the forensic quality of images intended for one-to-one comparison. These processes specifically apply to the preparation of a facial image for the purpose of submitting it as a probe into an automated FRS search to maximize the likelihood that an investigative lead will be returned among the candidates. These processes are not to be used for identification purposes.

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[3] Available from https://www.iso.org/standard/38749.html

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5.2 Important Notes

- The goal of any image processing should be to optimize the image for searching by the FRS, not to create an aesthetically pleasing image to the facial examiner. An image that looks 'good' to a facial examiner is not necessarily the same as one that is optimized for use by an FRS due to image processing done within the vendor specific algorithms.

- The effect of any manual image processing will vary with different FRS and in some cases may degrade performance rather than improve it.

- Image processing to the probe image before an FRS search is different from the operational processes performed by a facial examiner for the purpose of a one-to-one manual comparison.

- Any facial examiner based decision regarding whether or not a candidate returned from an FRS search is from the same source as the probe image must be made based on a comparison with the original (unedited) image and NOT the processed image.

- Agency specific or mandated notes and audit trails should be done at all times. Care should be taken to document and preserve processed images that both did and did not yield or improve the candidates in search results.

The following sections of this document describe a progression (minimal to complex) for the manual processing of probe images of less than optimal quality for an FRS. They are intended to maximize the likelihood of obtaining an investigative lead while minimizing the amount of processing of the probe image. Guidelines presented in this document may be adapted for agency specific policies and standard operating procedures.

The intended audiences for this document are agencies that have deployed an FRS and are looking for operational processes that may increase the likelihood of locating investigative leads from search imagery.

6. Procedure

6.1 Initial Steps

The initial steps for the management of probe imagery include, but are not limited to, the following:

1. Receive image
   Images are received depending upon agency policy in a variety of methods including but not limited to:
   - Agency approved e-mail
   - Agency approved media: CD, DVD, thumb drives, other
   - Agency approved file transfer protocol (SFTP)
   - Agency approved postal mail
   -

2. Save original
   A read-only copy shall be made of the original probe images. No enhancements or modifications shall be made to these original probe image(s). When making any final comparisons, the facial examiner shall always revert back to a working copy of the original probe image(s).

3. Make lossless working copies

   All image processing steps should be done using a lossless (uncompressed) file format.

Understanding the compatibility of image file formats for a FRS is critical because the original images may be received in a variety of file formats. If a probe image is not in an FRS compatible format, follow the vendor's recommendations for conversion to a supported compatible format. This conversion (if needed) should be done as a last step from the lossless images being processed, prior to searching.

6.2 Generalized Search Steps

For the purpose of this document, "pass" refers to an assumption that following each progression of image processing, an FRS search will take place and the resulting candidates will be assessed. In practice it may not be prudent to run the probe image through an FRS search until it has been processed to a certain degree. In all examples of "passes" presented in this document it is assumed that for every sequential "pass", the following steps shall be undertaken in every FRS search of a probe image.

1. Verify eyes can be found. The ability to locate the eyes in a facial image is intrinsic to every current FRS. Finding the eyes is fundamental to

locating the face in the image and to potentially distinguish other facial landmarks: nose, mouth, chin, cheeks etc. For imagery which meets ANSI/NIST- ITL-1-2011 specifications, it is not uncommon to have 1-3% of the images fail eye finding. For imagery which does not meet ANSI/NIST-ITL-1-2011 or ISO specifications then eye finding failures can easily exceed this range.

Verify that the eyes are correctly located by the FRS biometric algorithms being used to ensure that usable results are returned from the search. It cannot be assumed that because the eyes are visible and verifiable to the facial examiner that the eye finding process in the FRS can properly locate them. A manual check of the automated eye detection should be performed to ensure the correct positioning; if the positions are incorrect the eye locations should be manually located on the face in the image before submitting the image to an FR search so the manually placed eye locations can be used by the FRS algorithm instead of vendor specific eye finding.

Agencies should ensure that their FRS includes a tool or utility to automatically and manually identify the eye location in any facial image. This is critical for enabling facial examiners to determine if the facial imagery they are utilizing has limitations or systemic image conditions which may cause a problem when submitting to the proprietary technology within an FRS.

2. Save interim image sets – All processed images used for searching shall be saved according to agency policy. A facial examiner may find that searching images with different enhancements (e.g. cropped, black and white, or grayscale) results in different candidate sets.

3. Search and review results – FRS results should be compared against the original probe image(s). If no potential investigative leads are returned in the candidate list, the recommendation is to re-evaluate the image that was used in searching and apply further processing.

4. If available within the FRS, consider using metadata binning. The FISWG document *Facial Recognition Systems Metadata Usage[4]* should be referenced where metadata is accessible which refines searches through reducing the logical size of the search database.
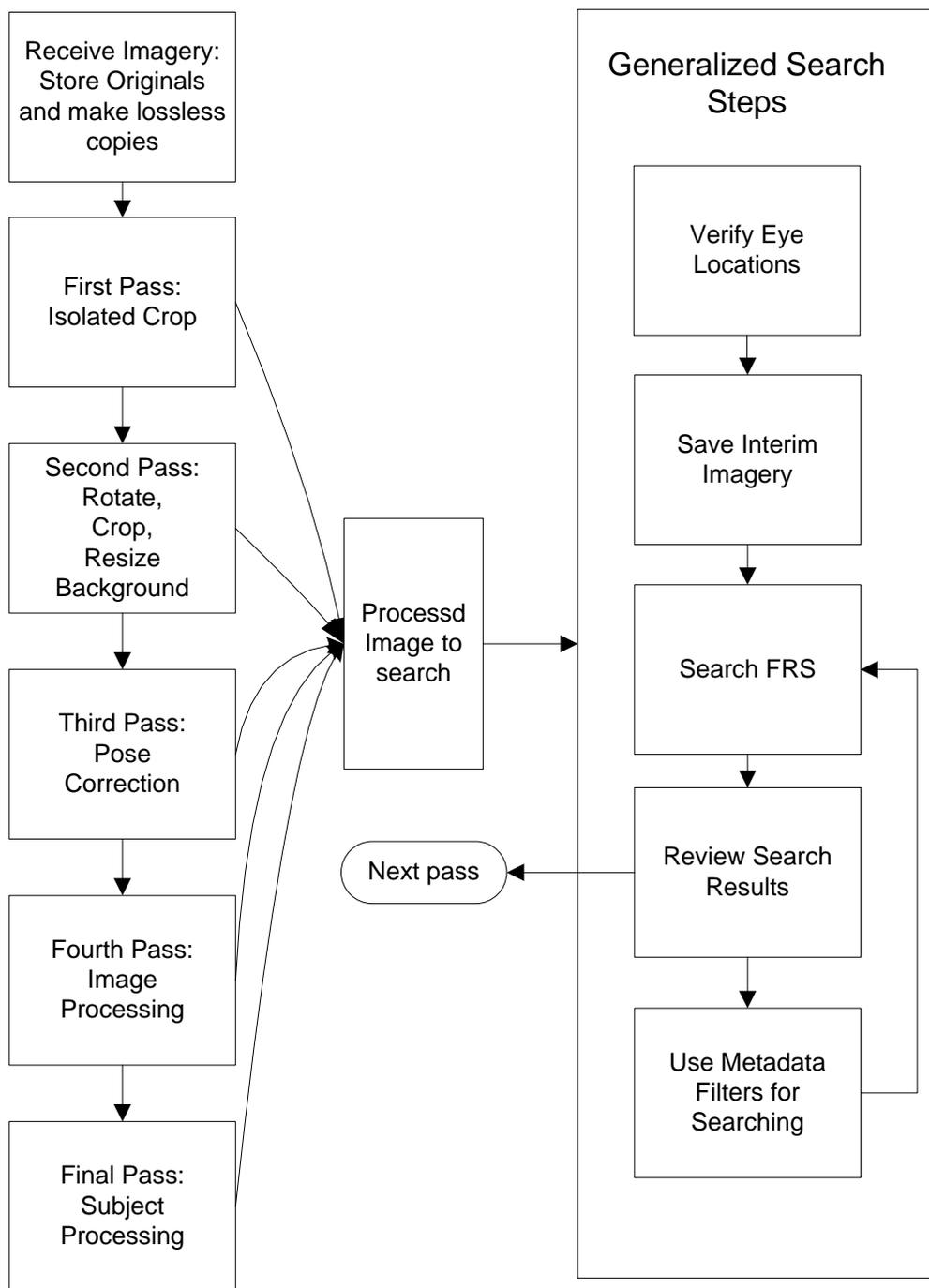
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[4] Available from: https://www.fiswg.org/document/viewDocuments

Figure 1: Simplified Image Processing Flow Chart

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6.3 First Pass: Original Image Search

The *First Pass* should be initiated with the original image where, if necessary and not undertaken automatically by the FRS, the relevant face(s) should be cropped. When cropping, ensure that the aspect ratio is maintained and aim to produce an image that is, as far as possible, in accordance with ANSI/NIST-ITL-1-2011or ISO specifications.

6.4 Second Pass: Isolated Face

A Second Pass would be initiated when no investigative leads are found during the First Pass and minimal further processing of the probe image could be carried out to yield additional candidate sets for review. The process can be carried out even if the First Pass yields an acceptable outcome and more candidates could be of additional investigative value or if the facial examiner decides that the nature of the image warrants Second Pass processing prior to the initial FRS search.

The Second Pass may include the tasks below which are not necessarily sequential. However, if more than one is applied, where possible they should be performed one at a time in the order in which they are presented below. When processing images, care should be taken to not remove or alter portions of the subject's head (e.g. portions of the ear, crown of the head, or portions of the neck).

- Rotate – The image may be rotated around the roll axis to make the eye positions appear horizontally aligned.

- Secondary Crop – The image processing steps done in this pass may require a secondary crop of the image. If this is done, the goal of this crop is again to produce an image that is more in accordance with the ANSI/NIST-ITL-1-2011or ISO specifications.

- Resize – Modify the size of the image to achieve a recommended inter pupillary distance. This distance should be agency defined for facial examiner consistency and based on FRS vendor recommendations (e.g. 90 pixels).   If resizing is done, then resizing of the images should be done in even multiples of the original image size while preserving the original image aspect ratio.

- Blur background – This is performed where the probe image has a non-neutral or busy background. The blurring process creates a consistent background preventing an FR engine from detecting items in the background. Examples include:

    o Surveillance photo with people or items in background;

    o An image captured with a background that varies in color and content

- Horizontal flip should be utilized if the probe image submitted may have been taken as a reflection, captured incorrectly, or been flipped left/right or right/left in transmission.

- Aspect ratio corrections.

6.5 Third Pass: Pose Correction

FRS algorithms have varying sensitivities to non-frontal facial imagery.   Claims of performance degradations will vary, but it is broadly accepted that any non-frontal pose movements will negatively affect FRS performance.

The standard definitions of pose angles are defined in:

NIST Special Publication 500-290 Edition 3 (2015)

ANSI/NIST-ITL 1-2011 Update: 2015

Data Format for the Interchange of Fingerprint, Facial, & Other Biometric Information[5] as referenced in Figure 2 below:

The Yaw and Roll angles shall be measured from the full face pose position and have a range of values from -180 degrees to +180 degrees. The Pitch angle shall have a range of values from -90 degrees to +90 degrees. The pose angle set is given by Tait-Bryan angles as shown in Figure 26.

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[5] Available from: http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.500-290e3.pdf
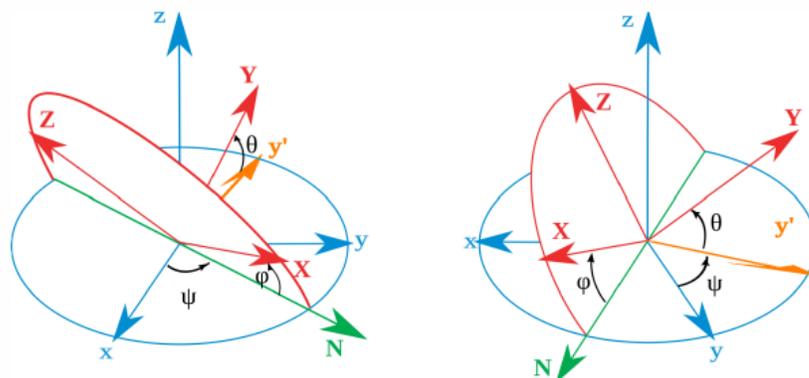
ANSI/NIST-ITL 1-2011: UPDATE 2015

Figure 26: Tait-Bryan angles statically defined with the Z-X'-Y" convention

The angles are defined relative to the frontal view of the subject, which has angles (0, 0, 0). Examples are shown in Figure 27.

Yaw angle: rotation about the vertical (y) axis. A positive Yaw angle is used to express the angular offset as the subject rotates from a full-face pose to his or her left (approaching a right profile). A negative Yaw angle is used to express the angular offset as the subject rotates from a full-face pose to his or her right (approaching a left profile).

Roll angle: rotation about the horizontal side-to-side (x) axis.

Pitch angle: rotation about the horizontal back to front (z) axis.

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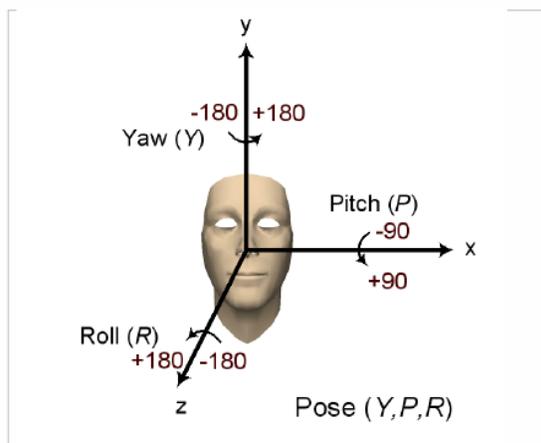
ANSI/NIST-ITL 1-2011: UPDATE 2015

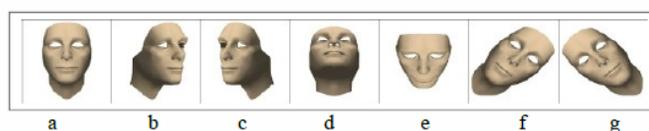Figure 27: Pose angle set is with respect to the frontal view of the subject

Figure 28: Examples of pose angles and their encodings.

The pose angles (Y, P, R) of (a) – (g) in Figure 28 are given by (0, 0, 0), (+45, 0, 0), (-45, 0, 0), (0, -45, 0), (0, +45, 0), (0, 0, -45), and (0, 0, +45), respectively.

The uncertainty in the pose angles is given by the range 0 to 90, inclusive. It shall denote approximately a maximum value of possible deviation in the measurement of the pose. This shall correspond to a two standard deviation confidence interval.

The encoding of angles is in ASCII format, with the minus sign "-" used to denote a negative value and the plus "+" sign optionally used to denote a positive value. Pose angle uncertainty angles are always positive.
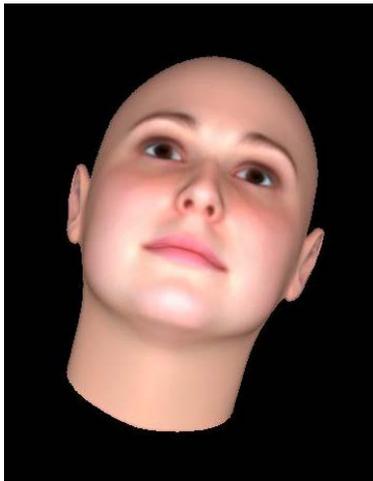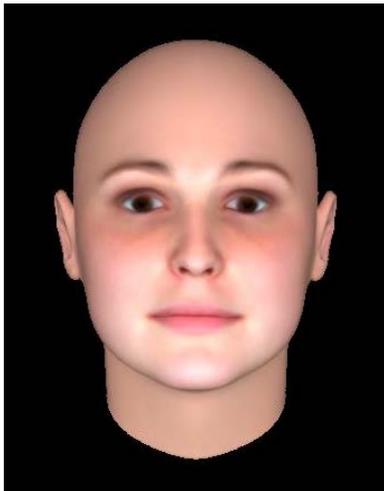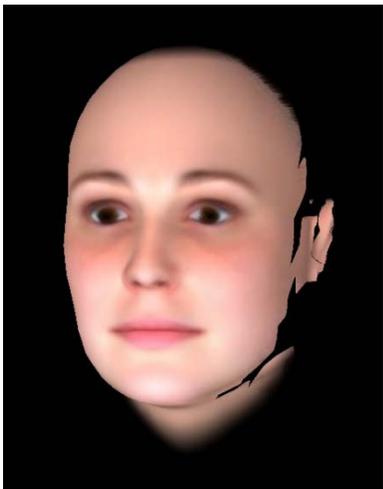
Figure 2: NIST Special Publication 500-290 Edition 3 (2015)
Section E.7.1: The definition and range of pose angles

Software for pose correction is dependent on policy and/or vendor recommendations, and should be deployed to trained facial examiners. In broad terms, any pose which varies more than 5-10 degrees in any direction from (0, 0, 0) could be considered a candidate for pose correction.

When pose correction is done, consideration shall be given to the following areas:

- What options exist within the pose correction model?

    o Does the pose correction software allow for a gender, race, or other assumption for doing the pose correction?

    o Does the software allow for a "fill" for areas exposed during the pose correction?

    o How many landmarks are needed? Eyes, nose tip, center mouth etc. could be requested for facial examiner placement.

    o There may be other settings within the pose correction modeling software which allow the facial examiner to manually fit a pose correction mask onto the face.

- How many corrected poses can be generated?

    o At a minimum, generate a frontal pose.

    o Multiple poses may also be generated:

        ▪ Frontal

        ▪ Slight left and right pose (e.g. +/- 15 degrees yaw)

        ▪ Slight up and down pose (e.g. +/- 15 degrees pitch)

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Pose	Example Image	Pose	Example Image
Original Image		Pose corrected frontal	
Yaw -15 degrees		Yaw +15 degrees	
Pitch +15degrees		Pitch -15 degrees	

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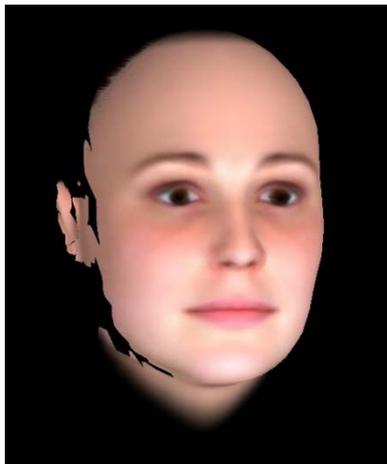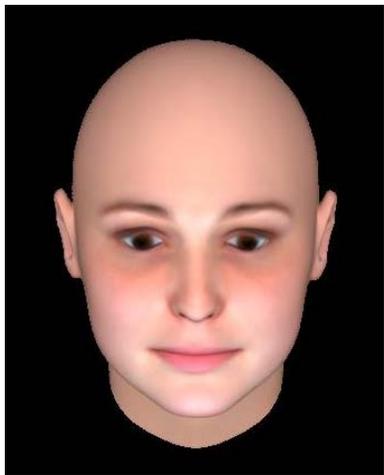
- When multiple poses are generated, searching each pose as individual probe images within unique searches may allow for pose variations within the gallery.   Some FRS supplied search clients allow group searching where groups of related imagery can be searched and reviewed in bulk. See appropriate vendor supplied manuals on how to use this option if available.

6.6 Fourth Pass: Image Processing

Image processing may be applied to a working copy of the original image or an image resulting from any of the previous passes to attempt to produce a different candidate list for review. The facial examiner may decide to use image processing steps which are directed at the overall image.

Image processing is performed external of the FRS using widely available image editors (e.g. Adobe Photoshop and GNU Image Manipulation Program [GIMP]) with the resulting probe image being submitted for an FRS search. The image processing listed below may be applied to the entire image or to selected regions within the image and may include, but are not limited to:

- Histogram equalization

- Color/tint corrections

- De-blurring or sharpening

- Lens distortion correction

  - Some images, such as those from smart phones, automated teller machines (ATM's) and Body Worn Video cameras that use wide-angle lenses typically exhibit significant perspective ('barrel') distortion. Image processing software should be used to correct for this prior to enrollment. Some manufacturers provide lens correction data, in which case these values should be used to ensure the proper correction is applied.

- Grayscale conversion

- Noise reduction

- Brightness or contrast adjustment

- Red eye reduction

6.7 Advanced Topic: Subject Processing

After previous passes have been completed (or rejected due to the nature of the image), the facial examiner may decide to use additional processing steps which are targeted at the subject in the image.

This type of processing may introduce external elements to the subject in the image. The facial examiner should follow agency procedures to determine whether these measures can and should be applied to improve the likelihood of locating an investigative lead from an image returned in the candidate list from an FRS search.

> **Reminder: Any decision on whether or not a particular candidate from a search is from the same source as the probe image shall be made using the original (unedited) image.**

Circumstances warranting this type of image processing include, but are not limited to, the following:

- Facial landmarks obscured by accessories (e.g. hats, scarves, or eyewear), hair, image artifacts etc.

- Missing or obscured facial landmarks due to extreme pose or expression (including closed eyes)

- Intentional alterations of the subject's face (e.g. excessive make-up)

- Trauma (e.g. lacerations, blood, bruising), evidence of medical intervention (e.g. bandages, endotracheal tube, neck brace) or post mortem.

Examples of subject image processing include, but are not limited to, the following:

- Replace or create missing facial landmarks on the subject.

- Mirroring the probe image on the center line of the half face.

Subject Processing shall only be performed by trained facial examiners when permitted by agency policies.