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Facial Recognition System: Image Processing to Improve Automated Facial Recognition Search Performance

Purpose

The purpose of this document is to provide facial reviewer 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. The processing techniques presented in this document represent the opinions of the current operational facial practitioners in the FISWG and NIST OSAC committees.

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.

Introduction

Images that meet agreed upon international standards (such as ISO/IEC 19794-5: Face Image Data) can normally be submitted to an FRS for searching with little or no operator intervention. Many FRS also include intrinsic mechanisms for correcting for minor deviations in subject pose, image size or vendor specific adjustments to the image. Manual processing by a trained reviewer may be beneficial for sub-optimal images (e.g., low resolution or heavily compressed images 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.

FISWG FR Systems: Image Processing to Improve Automated Facial Recognition Search Performance

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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 following an FRS search.

Important Notes:

- The goal of any image processing should be to enhance the image for searching by the FRS, not to create an aesthetically pleasing image to the reviewer. An image that looks ‘good’ to an examiner is not necessarily the same as one that is optimized for use by an FRS.

- 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 reviewer for the purpose of a one-to-one comparison.

- Any decision regarding whether or not a particular candidate from a 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.

The following sections of this document describe a linear 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. Agency specific notes and audit trails should be done at all times.
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:
   - Secure e-mail
   - Media: CD, DVD, secure thumb drives
   - Secure file transfer protocol (SFTP)
   - Properly packaged postal mail

2. Save original
   A read-only copy should always be made of the original probe images. No enhancements or modifications should be made to these original probe image(s). When making any final comparisons, the reviewer must always revert back to 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, the vendor’s recommendations for conversion to a supported format should be followed but this conversion (if needed) should be done as a last step from the lossless images being processed immediately before searching.

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 should 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 every other facial feature point: nose, mouth, chin, cheeks, etc. Eye finding errors are not unusual and can occur in a small percentage of facial imagery which appears “normal” to the reviewer. For imagery which meets ANSI, NIST or ISO Specifications it is not uncommon to have 1-3% of the images fail eye finding. For imagery which does not meet ANSI, NIST or ISO Specifications then eye finding failures can easily exceed this range.

It is imperative to verify the eyes are locatable 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 reviewer 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 positioned before submitting the image to an FR search.

Agencies should ensure that their FRS includes a tool or utility to automatically or manually identify the eye location in any facial image. This is critical for enabling reviewers 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 – Any copies of processed images used for searching should be saved. A reviewer may find that searching images with different enhancements (e.g., cropped, black and white, grayscale, etc.) 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* ([https://www.fiswg.org/document/viewDocuments](https://www.fiswg.org/document/viewDocuments)) should be referenced where metadata is accessible which refines searches through reducing the logical size of the search database.
First Pass: Cold Search

The First Pass should be initiated with the original image where, if necessary and not undertaken automatically by the FR system, 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 or ISO specifications.

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 reviewer decides that the nature of the image warrants Second Pass processing prior to the initial FRS search.

The Second Pass may include the following tasks. These tasks are not necessarily sequential; however, if more than one is applied, they should be performed one at a time in the order in which they are presented, where possible.

- Rotate – The head may be 2D rotated along the horizontal axis of the eye positions to straighten the facial image.
- Secondary Crop – The image processing steps done in this pass may require a secondary crop of the image. If this is done, then aim of this crop is again to produce an image that is more in accordance with the ANSI, NIST or ISO Specifications.
- Resize – Modify the size of the image to achieve a recommended interpupillary distance. This distance should be agency defined for reviewer consistency and based on FRS vendor recommendations (e.g., 90 pixels).
- Blur background – This would be 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:
  - Surveillance photo with people or items in background
Third Pass: Pose Correction

Various 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 is defined at:

The definition and range of pose angles

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.

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.
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 always are positive.

Access to software to do pose corrections is dependent on agency policy and/or vendor recommendations, and should be deployed to trained reviewers. 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.

If pose correction is done, attention should be given to the following areas:

- How the pose correction model fits to the uncorrected face:
  - 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 reviewer placement.
o There may be other settings within the pose correction modeling software which allow the reviewer to manually fit a pose correction mask onto the face.

- How many corrected poses can be generated?
  o It is recommended that a frontal pose is generated.
  o Multiple poses may also be generated:
    - Frontal
    - Slight left and right pose (e.g. +/- 15 degrees)
    - Slight up and down pose (e.g. +/- 15 degrees)

<table>
<thead>
<tr>
<th>Pose</th>
<th>Example Image</th>
<th>Pose</th>
<th>Example Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original image</td>
<td>Pose corrected frontal</td>
<td>Pose corrected frontal</td>
<td>Pose corrected frontal</td>
</tr>
<tr>
<td>15 degrees to the left</td>
<td>15 degrees to the right</td>
<td>15 degrees to the right</td>
<td>15 degrees to the right</td>
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</table>

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Search each pose as individual probe images within unique searches. 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.

**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 reviewer may decide to use image processing steps which are directed at the overall image. This process may be time consuming and may still yield no investigative leads.

Image processing is performed external of the FRS using widely available image editors (e.g., Adobe Photoshop, GIMP, etc.) 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
- Grayscale conversion
- Noise reduction
- Brightness and/or contrast adjustment
• Red eye reduction
• Aspect ratio corrections

Advanced Topic: Subject Processing

After previous passes have been exhausted (or dismissed due to the nature of the image), the reviewer may decide to use additional processing steps which are directed at the subject in the image. This process may be time consuming and may still yield no investigative leads.

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

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

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

• Facial features obscured by accessories (e.g., hats, scarves, eyewear, etc.), hair, image artifacts, etc.
• Missing or obscured facial features due to extreme pose or expression (including closed eyes)
• Intentional alterations of the subject’s face (e.g., excessive make-up)
• Trauma (lacerations, blood, bruising, etc.), evidence of medical intervention (e.g., bandages, endotracheal tube, neck brace, etc.) or post mortem.

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

• Replace or create missing facial features on the subject.
• Mirroring the probe image on the center line of the half face.
• Horizontal Flip should be utilized if the probe image submitted was may have been taken as a reflection or may have been flipped left/right or right/left in transmission.

Subject Processing should only be performed by trained reviewers when permitted by agency policies.

FISWG FR Systems: Image Processing to Improve Automated Facial Recognition Search Performance

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Reference List

FISWG documents can be found at: www.FISWG.org

ANSI/NIST-ITL Standard Homepage:
http://www.nist.gov/itl/iad/ig/ansi_standard.cfm
Flow Charts

Receive Imagery: Store Originals and make lossless copies

First Pass: Isolated Crop

Second Pass: Rotate, Crop, Resize Background

Third Pass: Pose Correction

Fourth Pass: Image Processing

Final Pass: Subject Processing

Generalized Search Steps

Verify Eye Locations

Save Interim Imagery

Review Search Results

Use Metadata Filters for Searching

Verify Eye Locations

Save Interim Imagery

Review Search Results

Use Metadata Filters for Searching