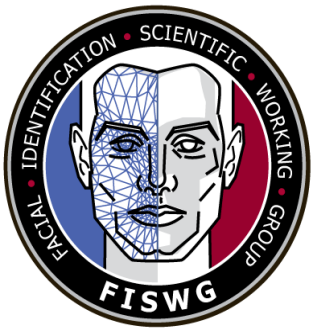

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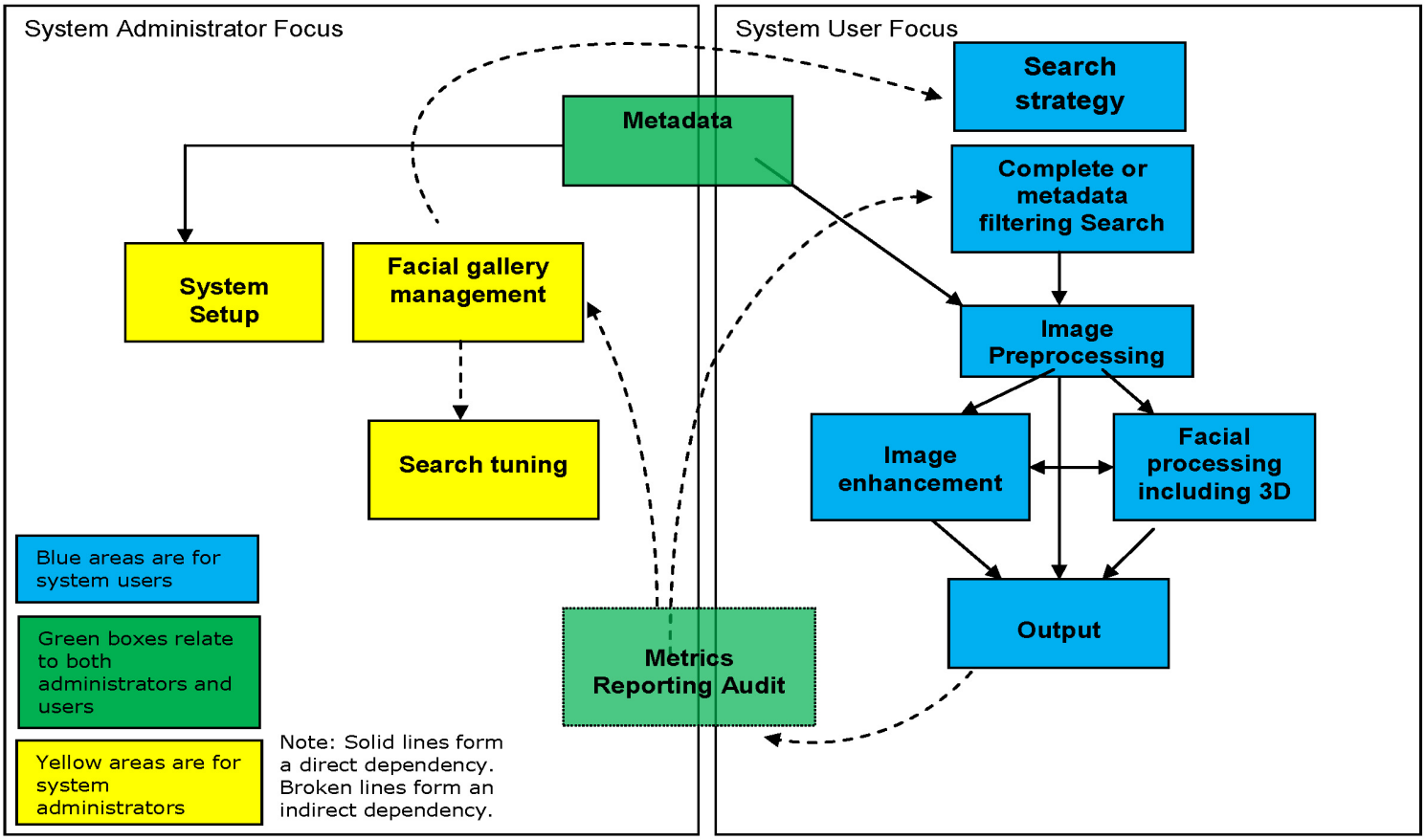
Facial Recognition Systems Methods and Techniques

Facial Recognition System: Methods and Techniques

This document provides a general outline of **Methods and Techniques** that can be helpful or considered when planning or operating a Facial Recognition (FR) system. The goal of this document is to provide guidance on methods and techniques to increase the likelihood of obtaining a true match in the candidate list for a submitted probe within a 1:N search. Please refer to the FISWG web site for guidance on human 1:1 comparison processes that may be required following a 1:N search.

Figure 1 is important to both system administrators and system users as it displays the relationship and information represented by the system, the flow of search strategies, and the management of the data in the facial gallery.

Figure 1 – System Flow (post enrollment)



NOTE: FISWG defines metadata binning as: A technique used by a FR system to organize enrollment of data to facilitate and optimize searching using filters based on information associated with an image.1

Target audiences:

- System administrators or developers of the FR system.
  - System developers are responsible for the overall design of the system features that allow and enable these methods and techniques.
  - System administrators are responsible for verification and proper deployment, implementation, and usage of these methods and techniques.
- System users.
  - System users are the examiners, operators, or other personnel who actually utilize the system for facial searching purposes.

A number of areas are described in overview below. Each area will be covered in depth in future FISWG standalone specific documents:

1. Metadata system setup and usage
2. Facial gallery management
3. Enrollment of the facial image
4. Search tuning
5. Search strategy and options
6. Image preprocessing
7. Eye locations
8. Metrics reporting auditing

1. Metadata system setup and usage

   Metadata is anything associated with but excluding the facial image and can include a system generated identity number for the person and/or gender, image header information, age, race, scars, marks, tattoos, ethnicity, etc.

   Metadata usage can be broken down into two main areas: system setup of the metadata by the system administrators and actual usage of the metadata by the system users.

   Metadata binning and subsequent filtering is an efficient approach that utilizes investigative data to refine a search and improve search results. If the metadata associated with the probe image is available to the practitioner and the FR system being used allows a metadata search, metadata filtering could be used to refine the initial search or to further refine the search results. Agency policy should govern at what point metadata is used in the search process, and user preference or agency policy will determine whether filters are added separately or jointly. If refining a search using metadata filters is an option, experimenting to determine the results each filter will produce will assist the practitioner in learning the limits of this type of search.

   It is suggested that the initial search be conducted using only the probe facial image, with no metadata search included. This will result in the largest-possible candidate list for comparison purposes. Subsequent searches using metadata as a filtering tool can then be performed in an effort to produce a more specific result and the best candidate list for analysis. It is prudent to use metadata searches even if a likely candidate is returned as a

[1] *FISWG Glossary Version 1.1, dated 2/12/2012*

result of the initial search, as there may be additional photos/candidates available for comparison within the database that a metadata search would disclose. It is important to note that a photo-only or metadata-only search may result in candidates that the other method of searching would not. If the option is available, a subsequent metadata-only search may produce an additional useful candidate list.

Using metadata filtering to refine a search can also be used to test a FR system algorithm. Limiting a search to specific parameters while searching for an image that is known to be a part of the FR database can disclose algorithm problems if the known photo is not a part of the resulting gallery. Additionally, by observing how a system responds, for example, to an image-only search vs. a metadata-only search, a practitioner can improve his/her own search strategy.

Metadata system setup is the phase where the metadata accessible for FR system usage is defined and categorized. This requires the textual information (e.g., demographic, biographic, contextual etc.) associated with the facial images to be defined as pick lists, numeric ranges, dates, or free text.

Metadata may also be created from indirect information not directly associated with a person. Examples here include:

a) Recidivism
b) Criminal behavior correlations
c) Gang or other affiliations
d) Watchlisting
e) Categorizing metadata sets into larger groupings (e.g., Regional Originating Agency (ORI) sets)

If metadata is known at the time of the FR enrollment then this information can be used (e.g. binning) to logically reduce the size of the gallery to be searched/filtered in a controlled and deterministic manner. Usage of metadata should be appropriately integrated into the overall search strategy because improper usage can be detrimental to providing successful search results. If the consistency of the metadata is low (i.e. there are data entry errors where, for example, gender is incorrectly entered) then filtering based on this demographic will result in higher error rates and the correct match to the probe could be filtered out.

If binning is utilized then it should be understood that metadata usage is a logical pre-filter and is separate from the algorithmic portion of the biometric matching process. If the consistency is known to be high, binning can improve performance, both in time and likelihood of returning a true mate.

2. Facial gallery management

Facial gallery management can be described as:

a) Monitoring and maintenance processes done on the overall gallery as it grows and changes.
b) Facial search techniques tuned to the galleries that are not static, can be changed or adjusted.
c) Applying user access controls and restrictions to subsets of data that have been deemed operationally sensitive.

Operational performance can be more effective if data is organized per algorithm sensitive characteristics and appropriate search strategies are used. For example, small images may require a different search strategy than large images. Further, off pose face images may be better suited for one algorithm while frontal images may produce better results using

another algorithm. Data quality metrics, demographics, and contextual data can all be used to analyze, profile, locate, present, repair, or exclude images.

Facial gallery management can be broken down into two main areas: data profiling and data cleansing.

Data Profile

a) Facial galleries can be collections of various types and quality of imagery from different capture systems that can be characterized based on their core similarities (e.g., image file size, image quality, expression, etc.). This has also been referred to as "sameness". Galleries should be profiled in order to gain an understanding as to how many collections exist.
b) These collections can be managed and search strategies defined taking into consideration the aforementioned characteristics of the galleries that may improve search performance.
c) Proper profiling involves knowing the collections in the facial galleries. Operational pilots have shown significant increases in accuracy by choosing the appropriate search strategy for a given image set within a larger gallery of assorted images.

Data Cleansing

a) Many images in a facial gallery are sub-optimal due to reasons that include but are not limited to:
    - Non-frontal faces
    - Images not of a person
    - Incorrectly detected eye positions
b) These images need to be identified so they may be isolated, corrected, or marked for exclusion

3. Enrollment of the facial image

The timing of the enrollment of a facial image into an automated FR system will have an effect on 1) whether subsequent images are providing the most-comprehensive search and 2) the timing of a response to a requestor. The best-case scenario would consist of a near real-time operational environment – an FR system enrolling an image as the image is entered into the system to be searched. This would ensure that the image is enrolled to the system's photo gallery immediately, that it is immediately available to be searched against subsequent probe images, and that it is searched against every previously-submitted image maintained within the database. However, since all FR systems are not the same, this is not always the case.

With a time-delayed environment, some amount of time will pass before a probe photo is enrolled into the database following a search. If subsequent probes are searched prior to previous probes being enrolled (i.e., if an agency waits until a certain time of day to enroll all of the day's probe images), a possible candidate(s) may not yet be in the system's database and, therefore, cannot/will not be included in the resulting candidate list. Conversely, if an agency waits to search probes until the system has been updated by the enrollment of the day's previously-searched probes, searches will not be performed in a timely manner and investigations may be impeded. This is also true of batch process enrollments.

Practitioners should be aware of their agency's system enrollment policy and adjust their search strategy accordingly. If the system environment is not real-time the search of a probe image prior to the day's system update may necessitate a re-search of the probe once all of the day's images have been enrolled.

4. Search tuning
   The purpose of search tuning is to improve overall system performance. Search tuning is defined as analysis or testing that has been undertaken on operational data that results in a set of predefined or range(s) of settings or options that can be used when searching. Any search tuning should incorporate information from (i) system developer and/or integrator, (ii) objective testing/testers and (iii) operational user analysis with respect to the given FR system, its data, and its targeted goals.

   Information from the system integrator should include but is not limited to:
   a) What is the overall approach used for the FR system? Describe the FR system sensitivity to: geometric shapes of the face, facial features, skin texture, facial landmarks, or other facial representations.
   b) How much roll, pitch, or yaw can be tolerated before pose correction should be considered?
   c) Is there any known bias in the system (e.g., age, ethnic, other)?
   d) Is multi-pass searching used? If so what options exist to vary the search pass settings?
   e) Is there a trade-off between accuracy and search speed? If so, how is the intensity of the searching changed? Who can make these changes?
   f) How does facial gallery growth and size impact FR search times?
   g) How do you interpret a facial match score?
   h) Is any scoring normalization used or available? If so what types and kinds? Is each gallery dependent or gallery independent?
   i) Are there any effects on facial match scores as the gallery size changes e.g. quality of match performance with more images of more candidates?

   Objective tests can then help provide assurance that any information provided is accurate when it applies to critical statements or assumptions. Objective tests should be performed on ground truth data. If it is not possible to ground truth operational data then the test data should aim to be as representative as possible to the intended data type(s) of the system. For example, if the system is to be used with a combination of mugshot and surveillance images, then testing should be undertaken on galleries consisting of both of these image types.

5. Search Strategy
   As noted in previous FISWG documents, "it must be recognized that agencies (and individuals) perform facial comparison for a wide variety of purposes, often under operational conditions that do not allow for a great deal of time or effort to be expended. Agencies that choose to utilize such methods must recognize this fact and the associated risks (i.e., greater chance of error)."2 This applies to other operational constraints including, but not limited to, enrollment of images, varying system algorithms, requestor's directives, and agency policies. A comprehensive search is a trade-off. If agency-specific constraints such as workload, workforce, and/or deadlines and outside influences such as a requestor's directives are predominant concerns, results will suffer. Search strategies employed by practitioners should take into consideration any known policies, constraints, and customer expectations.

[2] *FISWG Guidelines for Facial Comparison Methods Version 1.0, dated 2/2/2012*

Agency policy and outside influence will dictate the extent of searches performed. Any system designed to hold operationally sensitive data needs to consider levels of user access and restrictions to subsets of data. Operational policy should be an agency decision, but workload, workforce, and deadline may dictate and constrain searching strategy/possibilities and, therefore, results. As previously noted by FISWG, "Facial comparisons are performed for a number of reasons and the comparison methods employed should be chosen based on the timeframe required for a decision and the level of confidence required. Comparisons that need to be immediate require the use of faster processes that will necessarily lead to a result with a lower confidence. In certain scenarios, this lower confidence is an acceptable trade-off for the speed of the analysis."3 This applies to a modified searching strategy resulting from policy-driven or requestor constraints, as well.

Requesting agencies potentially constrained by policy, may ask that certain procedures be followed, such as a request to search by specific metadata, to search additional databases that are external to the initial searching agency, or even to request there be a certain (i.e., limited) number of images in the candidate list that is returned. In such cases, search results will be dependent on information provided by the contributing agency, and results may differ from those that would be produced had no constraints or directives been issued.

In all contingencies, the practitioner must understand his/her FR system's capabilities and limitations before asking it to search by specific information, and in order to develop the best strategy for his/her operational environment and the constraints put in place by the agency and/or the requestor.

Search options are defined as the options or feature sets a user has at their disposal when doing a facial search. This is the culmination of all methods and techniques defined within this document, that if done properly should increase the likelihood of a successful search.

Accurate comparison of facial images is highly-dependent on the quality of both the probe and the gallery image. A practitioner's ability to note similarities and differences between the probe and gallery image(s) is reduced when both are not of optimal image quality, and he/she may be unable to reach a definitive conclusion.

Comparison of:

- **A high-quality probe against the high-quality portions of the facial gallery**

  As FISWG has noted previously, "Optimal images for facial comparison are high resolution and have sufficient focus to resolve features of interest, such as blemishes and wrinkles, with minimal compression artifacts or distortion…"4 The obvious advantage to comparing a high-quality probe against a high-quality gallery image is that, with pristine images, the practitioner will be able to clearly view, on each image, every feature that is typically compared during the morphological analysis of the face. The higher the quality of the probe image, the better the chance of producing a candidate list that will result in a likely candidate and the stronger the conclusion that can be drawn.

[3] *FISWG Guidelines for Facial Comparison Methods Version 1.0, dated 2/2/2012*
[4] *FISWG Guidelines for Facial Comparison Methods Version 1.0, dated 2/2/2012*

- **A low-quality probe against the high-quality portions of the facial gallery**

  Each agency and practitioner will have his/her own definition of what constitutes a low-quality probe image. These include, but are not limited to, distorted photos, low resolution face, and limited dynamic range, each of which impede the practitioner's ability to clearly discern the subject's facial features. A FR system may accept a less-than-optimal probe image, but the lack of discernible facial features will result in a less-than-optimal candidate list, regardless of quality of the photos within the FR system. If an experienced practitioner with the proper training in the analysis of such photos is able to discern a clear feature on a poor-quality probe image, he/she will be more likely to match the probe to a gallery image; however, the conclusion drawn may be weak. Metadata binning may be considered as a way to improve searching/filtering candidates that closely match general, obvious, or known features of the probe image. The best-case scenario may be to utilize this situation as an opportunity to eliminate those photos with obvious differences, and/or offer any conclusions drawn to the requestor as an investigative lead as opposed to identification.

- **A high-quality probe against the low quality portions of the facial gallery**

  While a high-quality probe will increase the probability of a more thorough image search against the photos within a FR system and may produce a more comprehensive candidate list for comparison, the gallery may still include images of low quality. As with the scenario noted above, if an experienced practitioner with the proper training in the analysis of such photos is able to discern a clear feature on a poor-quality probe image, he/she will be more likely to match the probe to a gallery image; however, the conclusion drawn may be weak. Metadata binning may be considered as a way to improve searching/filtering candidates that closely match general, obvious, or known features of the probe image. The best-case scenario may be to utilize this situation as an opportunity to eliminate those photos with obvious differences, and/or offer any conclusions drawn to the requestor as an investigative lead as opposed to identification.

- **A low-quality probe against the low-quality portions of the facial gallery**

  Obviously the most-challenging scenario, the submission of a low-quality probe image for search by an FR system will return a less-than-optimal candidate list, and the comparison of a low-quality probe against a low-quality gallery image should be attempted only by an experienced practitioner who has been properly trained in handling this type of comparison. Metadata filtering may produce a more productive candidate list than image search alone, but poor quality renders it difficult to discern blemishes, shapes, and features of the face. Practitioners will be less able to render definitive conclusions. Eliminations may be easier to make based on gender, race, and ethnicity.

Example operational scenarios that should be discussed include:

a) When and how to use metadata filtering when searching
    - Are there specific instances where metadata filtering can be used or should not be used?
    - When searching the gallery, should the search start with no filtering, followed by adding metadata filters? Or should metadata filtering be applied on the initial searches and then removed or altered based on the character and content of the result sets?
b) How is the searching strategy affected by having multiple probes?
    - Using the same image with different variations from image preprocessing
    - Using multiple images of the same person of interest in entirely different images
c) How or when can the number of results be changed to augment the search process?
d) How can the options or features in the biometric algorithm be used to augment the search process?

Search strategies should also be planned around any known operational constraints. An example of this is how or when new images are enrolled into the gallery and does this affect how facial searching is done on new probes that need to be searched? If gallery images are enrolled twice a day, does this cause a deliberate time delay in searching a new facial image?

Within the context of this document, metadata filtering is assumed to be done within the search process and not a post search user based operation. If the client used for reviewing search results offers post search filtering, then this can greatly enhance the reviewing of candidate list results.

6. Image preprocessing

Ideally, image preprocessing enhances a probe facial image in order to improve the matching prospects. The system developer should provide any appropriate guidelines for optimized facial data to be used by the system. Preprocessing should only be done on poor quality images as determined by the quality attributes provided by the developer or quality metrics supplied by the face recognition system. Improper use of image preprocessing can degrade system performance and therefore only properly trained personnel using industry accepted image processing applications within approved agency guidelines should perform image preprocessing.

Image preprocessing can include both image enhancement and facial processing. In all steps the original image is always preserved for reference and forensic comparison purposes. It is left up to agency policy to determine if the original image should always be searched.

a) Image enhancement uses standardized 2D filters including but not limited to image lighting, histogram equalization, color corrections, de-blur, etc.) Such enhancements are strictly reliant on information within the image itself. The geometric aspects of the person in the facial image are NOT changed when doing this.
b) Facial preprocessing is applied to just the face to clarify and improve the facial image in order to render a more compliant search probe. Techniques include three dimensional modeling such as pose correction. These are separate and distinct from two dimensional modifications because the geometric aspects of the person in the facial image are changed when doing this.

Some current FR systems provide options, although they may be limited, that will allow a

practitioner to enhance a probe image, as necessary, once it has been submitted to the system for search. Much like enhancements made with software such as Photoshop®, these options will permit a practitioner to make changes to the original probe photo, therefore allowing a more comprehensive search and possibly resulting in higher ranked or additional candidate list images. If a FR system produces a poor candidate list, the user can take advantage of image preprocessing.

Such enhancements could include, but are not limited to:

a) Adjusting brightness
b) Adjusting colors/tinting
c) Adjusting contrast
d) Cropping the image
e) Enlarging the image
f) Adjusting roll, pitch, or yaw
g) Marking the center of eye
    - May help algorithm with eye placement
    - Distance between eyes may also assist search parameters
h) Adding metadata to the search (e.g., sex, race, etc.) after the initial image search

A practitioner may find that searching a number of probe photos, the same image with different variations of enhancements, and/or multiple images of the same subject – provided the images are clear – improves the chances of an image search resulting in a candidate. However, regardless of how many probes are submitted by a requestor or to what extent the practitioner enhances the probe, all available probe images should be searched, and the same basic search strategies should be used.

Using Photoshop® or comparable software, probe images can be modified from color to black and white or enhanced, as necessary, to reveal facial features. At the discretion of the practitioner, the image search can begin with the best probe image or all available probes can be submitted for search at one time. Regardless of the search order, all available probes should be searched, whether it is assumed that any will be rejected by the system, or whether a candidate list has already been produced as a result of any other probe. Using this approach will ensure a comprehensive search and a more robust candidate list for comparison purposes. All candidate lists resulting from the search of any of the probe images should be reviewed.

If metadata is submitted with a probe image, a metadata search should be conducted, regardless of the size of the candidate list returned as a result of the image searched.

7. Eye Locations

In all steps involving image preprocessing, it is key to ensure that proper eye location and verification is done. This is either a manual placement of eye locations on an image or the verification that the FR algorithm can automatically locate eyes in the final search probe.

Eye location verification is a key part of the facial image search process, and essential to an accurate image search by an automated FR system, as it improves the algorithm search. Agencies should take this into consideration when purchasing an automated FR system. Taking into consideration all existing FR systems, however, a practitioner may not have the option of marking the center of the probe photo's eyes prior to search. To ensure searching consistency, each agency should know how their FR system operates. For example will it mark the eyes (or the chin, or the ears)? Individual agencies should establish an eye location verification policy that will ensure that the center of the eye is marked prior to searching or, if this feature is not available, that the probe photo's roll, pitch, and/or yaw is

adjusted so the eyes are level. Agencies must be aware of how their FR system operates – this will drive policy.

8. Metrics Reporting and Auditing
This is defined as the collection, summary, and analysis of any and all information presented to, acted on, or produced by the FR system. The outcome of this can be used to understand the system operation, defend the performance of the system, or develop understandings of how to improve or optimize the system as a whole.

The following FR performance metrics may include:

a) Searches done
   - Date and time
   - Workstation
   - User
   - Search strategy
   - Metadata filter(s) applied
   - Probe characteristics
   - Search results

b) Average search time
   - Search strategy
   - Facial gallery size
   - Metadata filter(s) applied

c) Failure to acquire / inability to create template

d) Characteristics of the result sets
   - Number of results
   - Scores and distributions
   - Metadata of interest

e) Confirmed matches
   - Scoring
   - Ranking

f) Overall quality of the facial images as it pertains to the FR matching

These metrics should be routinely reviewed for continual operational tuning and overall effectiveness.

Reference List

FISWG Glossary, version 1.0

FISWG Guidelines for Facial Comparison Methods Version 1.0

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