To: Michael McCabe
National Institute of Standards and Technology (NIST)

Fm: Scientific Working Group on Friction ridge Analysis, Study and Technology (SWGFAST)

Re: ANSI/NIST ITL 1-2000 AMERICAN NATIONAL STANDARD FOR INFORMATION SYSTEMS – DATA FORMAT FOR THE INTERCHANGE OF FINGERPRINT, FACIAL, & SCAR MARK & TATOO (SMT) INFORMATION

Date: November, 2005

During the April, 2005 NIST meeting regarding the captioned standard in Gaithersburg, MD, an action item was tasked to SWGFAST to identify, define and provide guidance on additional fingerprint features beyond the traditional ending ridges and bifurcations currently in the standard, i.e., Type 9 Minutiae Data Record. During that meeting, SWGFAST presented the correlation between resolution/compression and the ability to reliably extract features beyond the current Type 9 minutiae. While it is recognized that the current standard of 500ppi and 15:1 WSQ compression will provide the ability to extract some of the additional features listed below it may not be sufficient to reliably extract the features or to take full advantage of the information content for improving latent print matching algorithms. We encourage vendors to exploit as many of these features with 500 ppi images as soon as possible at the same time to begin research and development that will incorporate these features with 1000 ppi images. However, we would be remiss if we did not state a stern warning that using 500ppi images with (or even without) lossy compression to extract much of the information listed below may actually result in unreliable data which in turn may not improve accuracy, or even worse, reduce accuracy. Performance testing and independent validation testing must be a part of the acceptance process.

The SWGFAST goals are:

1. **Increase fingerprint image quality.**
2. **Increase extraction of more fingerprint features.**
3. **Improve the reliability of extracted features**
4. **Improved latent print operations, both manually and in an automated system, by increasing identification rates and reducing risk of errors.**

SWGFAST, a group of latent print experts with an aggregate of over 800 years of experience have recognized that AFIS technology, since its onset, has utilized a very limited amount of fingerprint detail. Latent print experts must rely on far more information in effecting individualizations/exclusions than just ending ridges and bifurcations, i.e., the Type 9 minutiae record. SWGFAST is attempting to educate and provide to the vendor community the additional features and how they are utilized by these experts.

While the discussions during the Workshop focused primarily on Level 3 Detail, it was not the intent of SWGFAST to limit the issue to just Level 3 Detail. In fact, SWGFAST believes that the greater benefits will derive from the improvements of implementing more data from all three levels of detail. Emphasis needs to be redirected to this approach rather than just attempting to implement Level 3 Detail data into the standard. Therefore, the list below identifies additional information for each level of detail. It will be obvious from the list below that level three detail is less emphasized than the other two levels. This is due to the fact that SWGFAST believes that all three levels of detail are significant as an aggregate. Each latent print comparison conducted with a known exemplar will have varying degrees of quality and quantity of information. The quality of both images and the correlation of the quality areas between the two impressions will affect what can and can not be used in reaching a reliable conclusion. SWGFAST believes that in order to improve latent print performance the standard should provide for the listed data in all three levels of detail. Each comparison may need to depend on varying degrees of information depending on the quality and quantity of all features and may also vary depending on areas within the comparable area between two impressions.

Traditional AFIS technology extracts minutiae (ending ridges and bifurcations) using a process that first binarizes (or skeletonizes) a gray scale image for the detection of the minutiae. It is known that this process results in both missed and false minutiae. In order to achieve the objective of taking advantage of the additional fingerprint features listed below it is recommended that fingerprint extraction technology utilize the gray scale image without relying on the binary or skeleton image. At a minimum, using 1000ppi images should improve the current extraction processes.

SWGFAST knows that the information content listed below is present in fingerprints and can be relied upon in performing latent print examinations. It is also well understood that when these features are present and discernible that they must be relied upon in reaching accurate conclusions. The challenge is for AFIS technology to incorporate these features to improve latent print searching and matching accuracy. Improving accuracy is defined by the terms reliability and selectivity. How well does the algorithm select the correct mate (reliability) and how many candidates (selectivity) must be examined, e.g. correct mate within the top 3 candidates.

All of the features listed below can be used during human expert based comparisons to effect individualizations/exclusions from AFIS candidate lists. The challenge to the vendor community is to incorporate the same information into AFIS technology to improve matching accuracy. Adding this list to the standard provides consistency and ensures interoperability.

SWGFAST believes that the benefits associated with migrating to higher resolution fingerprint images and processing directly from the gray scale image will increase the accuracy of the extraction algorithms, the search algorithms and the match algorithms. Additionally, for manual comparisons, it will increase the ability to reach more conclusions (individualizations and exclusions) while decreasing the frequency of

inconclusive comparisons. It is our objective to increase latent print performance by a significant magnitude for both automated and manual latent print processes.

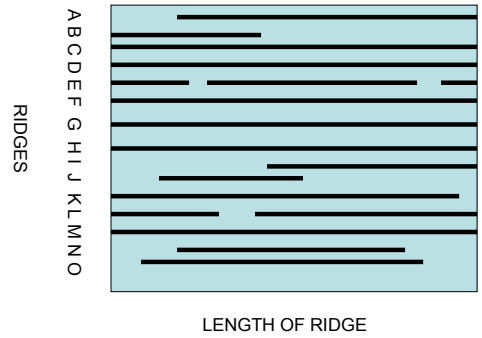
1a Ridges in sequence

If there is one key aspect to the SWGFAST proposal, it is to shift the entire approach away from the traditional AFIS matching concept based on "minutiae in sequence" to a new approach of "ridges in sequence." Instead of trying to simply add the following elements to the existing Type 9 minutiae record, we envision that a new approach of first capturing and using the "ridges in sequence" concept. This will become the basis for accurately detecting and properly utilizing any of the listed features below. This will require the Type 9 record to be significantly modified or, better yet, a new record type created.

What is meant by "ridges in sequence?"

If one were to take a fingerprint and take the first ridge above the crease and straighten it out and then take each subsequent ridge and straighten it out and placing it on top of the previous ridge but keeping its relationship in tact with the previous ridge, then you would end up with a chart similar to that below. Each ridge would then need to have recorded what occurs based on the list below. Is it a continuous ridge. Does it end and/or bifurcate and, if so, where (current X,Y, Theta data). What is its curvature. Where are the pores. What is the ridge width and variances along the ridge. Where does a scar interfere with the ridge(s). What is the relationship of the ridges (not just the relationship between minutiae, e.g. ridge counts between minutiae) And much, much more data being recorded. We are <u>not</u> proposing that this exact approach be done but is just an effort to demonstrate the concept of "ridges in sequence." Latent print experts do not look at just the minutiae, but rely on the ridges in sequence and then note where the features (and, again, not just minutiae) reside. Development of AFIS technology has skipped the ridges in sequence and went right for the "minutiae in sequence." We believe this to be a fundamental flaw in the evolution of AFIS technology and is precluding latent print performance from advancing to the next level.

RIDGES 'A' THRU 'O' FROM TOP.



Note: Please forgive my lack of drawing abilities. Ridge ‘E’ is truly three separate ridges and should be considered ‘E1,’ ‘E2’ and ‘E3.’ This also applies to ridge ‘L’ as ‘L1’ and ‘L2.’

Having stated the need for starting from “ridges in sequence” the following list of features can be added to the standard. Without understanding the “ridges in sequence” concept then most of this information will be extremely difficult to implement or define in the existing standard Type 9 record. Another important note is that we use the term fingerprint features instead of minutiae. This is to distinguish that a feature could be many aspects of the fingerprint. It could be a single event, such as minutiae is currently defined in the standard, or a single pore on a ridge. It could also be a series of ridges, such as the delta configurations in Level 1 Detail.

1b Exclusions

A second major limitation with current AFIS technology is the inability to make exclusions other than through the use of general fingerprint pattern classifications (arch, loop and whorl). The exclusion process is generally the easier of the two decisions (individualization or exclusion) for the human examiner, but is not adequately dealt with in AFIS technology. This may be due to the fact that all algorithms attempt to compute a probability of match score, never a probability of non-match score. One approach may be to utilize AFIS as currently designed (based on filtering with fingerprint pattern classification and minutiae based matching) and then process the resultant search candidates through a secondary scheme of matcher(s) that address both the identification and exclusion issue. While some of the features listed below may be difficult to implement (due to throughput and reliability issues) for a match based concept, they may be very advantageous for a non-match concept.

The point SWGFAST wants to make regarding both concepts of “ridges in sequence” and a non-match (exclusion) process is that the standard should provide for as many features about a fingerprint as can be defined and let the developers, algorithmists and vendors

decide how to best exploit this information. And may the best system make the most money. SWGFAST will be a willing resource for supporting the pursuit of these concepts.

1 Level 1 Detail

1a Ridge flow

Ridge flow – is a series of adjacent friction ridges in a directional arrangement. Most current AFIS technology captures this in a very crude fashion primarily for classification purposes and then dismisses the information from further processes. This is generally done by pre-defining an area of X horizontal pixels by Y vertical pixels and then record a singular indicator of the ridge flow for that area. This is then repeated for the entire fingerprint area – see example X. This approach is limited and misses the first key element of recording "ridges in sequence." This information should be used at the ridge level and for far more than just classification purposes.

Ridge flow can be used as a means to limit or restrict a search to a portion of a data base. Currently ridge flow is used to determine pattern type (arch, loop, whorl) and is used to filter through a data base. This approach is limited and does not take full advantage of ridge flow for a smaller area. Ridge flow as a smaller level than pattern classification is one potential area to support the exclusion concept.

If a series of adjacent ridges form an 'S' shape in the core area of a double loop type whorl, then the size and direction of the 'S' (forward or backward, upright or on its side) can be used as a feature. The size of the 'S' shape can also be extremely beneficial, e.g., a broad and elongated 'S' versus a very tight and short 'S' shape.

1b Cores and Deltas

Core formations as a series of ridges can often provide quick discriminators and can be used as a feature, e.g., the appearance of a happy face, letter or number in the core area. See examples below.

Study the images above. Do you see the 'smiley' faces? While each can be labeled a 'smiley' face, each is different. When one takes into account all three levels of detail, this small amount of area is sufficient to render a conclusion. Notice the dots in each image. Current AFIS technology does not recognize this critical feature. It needs to be included in the standard.

Cores and deltas, independently or as a correlation, are underutilized in AFIS technology. While cores and deltas are currently used for automatic classification, this information should be exploited in support of latent print searching and matching. It is recommended that cores and deltas be extracted to include their location, orientation, distance in relation to each other and other features. For example, cores can be further exploited by using a configuration of ridge flow, ridge path, minutiae and other features as a single measurement with weighted values.

Depending on the pattern type, the delta information may range from none (plain arches) to four (accidental whorls). Some minutiae extraction algorithms have the most difficulty around cores and deltas which have frequent occurrences of minutiae. The missed and false detection rate is usually quite high. By just defining the ridge flow, individual ridge paths and the ridge features (all combined provide for "ridges in sequence) in a small concentrated area, such as a core or delta, can provide better discriminating power than having 20 minutiae spread over a larger area.

Core/deltas – (fgpts/pps) the location and relationship for search and match purposes.

1c Finer level of classification

Finer level of classification – the old Henry Classification and NCIC classification schemes were extremely beneficial to latent print searching and matching but their use disappeared as the technology was focused on 10-print processing and the limited benefit a finer level of classification provided. While understanding the limited benefit a finer level of classification would have for 10-print processes the benefit for latent processes are still meaningful. It is possible that this finer level of classification could be utilized during a secondary filter/matcher. (Also, opportunity for exclusion concept.)

2 Level 2 Detail

2a Ridge Path

Ridge path – is the course of a single friction ridge. This ridge path has four elements as follows:

- **Continuous or Open Ridge** – a single ridge absent of any ending ridge or bifurcation for the visible area.
- **Minutiae/Ridge Relationship** – the association (type and distance) of ending ridges and/or bifurcations on a single ridge path. By default, a bifurcation will always be described from the single ridge path to the resultant two ridge paths at the point of

bifurcation. Enclosures (two bifurcations facing each other) will need to be further defined.

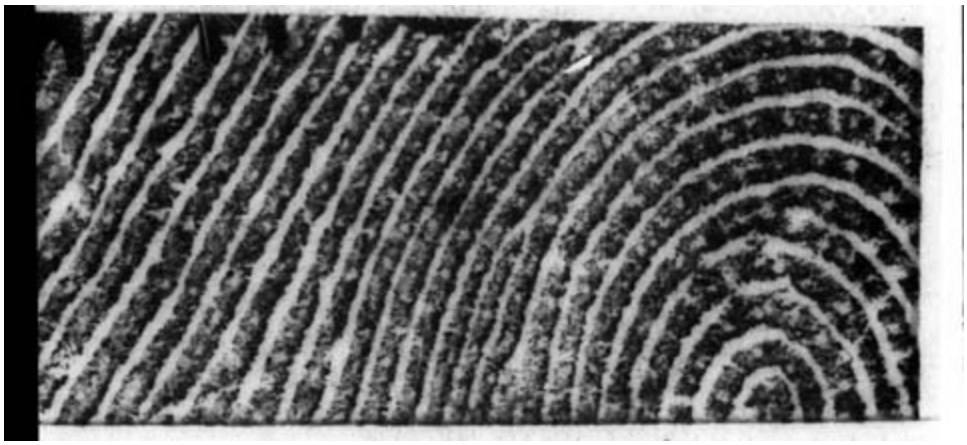
- **Ridge Curvature** – the path of a single ridge by measuring the distance, arc, directional deviation, etc.
- **Feature Relationship** – the association (type and distance) of pores, significant edge shape variances and significant ridge width variances.

Study the image above. Do you see the 'stick man'? Now look at the ridge that makes the outline of the 'stick man.' This ridge is unique. It has minutiae/ridge relationship, ridge curvature and feature relationship. The minutiae /ridge relationship is that there are two ending ridges. The ridge curvature is highly varied and uncommon. The feature relationship includes both level 2 and level 3 details. The shape of the ending ridges is different. The inside edges of the ridge that form the head of the stick man is significant. And, the relationship of all of these features is significant.

Current AFIS technology generally limits the size of the area of a fingerprint for minutiae extraction and the total number of minutiae. If the number of minutiae is exceeded then decisions are enacted as to which minutiae are deleted. Both of these issues work against latent print searching and matching and the limitations should be eliminated.

2b Open Field of Ridges

Open Field of Ridges – a series of adjacent ridges whose length is similar and where all ridges in the area are void of any ending ridges and bifurcations. The absence of minutiae on a single ridge path or in an open field area is just as important as the presence of an ending ridge or bifurcation on a ridge path. (Opportunity for exclusion concept.)



Start from the left side of the image above and note that there are approximately 15 adjacent ridges which are absent any ending ridges and bifurcations covering a significantly large area. Granted, that once the individual ridge paths are followed to the edge of the visible image there are a couple of features which appear that a bifurcation or ending ridge may exist. But the point is - there is a significantly large area void of any ending ridges and bifurcations. The absence of these ridge features is just as important as their presence.

2c Greater definition of minutiae

Greater definition of minutiae (shape and size) – finer level of description of the ridge ending shape and configuration of the actual bifurcation. (see the 'stick man' above for an obvious distinction of ridge end shapes.)

2d Scar

Scar – must cross two or more adjacent ridges. By definition, the size of scars will vary greatly. The location within the friction ridge impression along with directionality are essential. This information alone is very discriminating and can be coupled with the configuration of the scar, e.g. round, straight, curve, length and width, polygon. The effect of the scar on surrounding ridge paths will generate new unique ridge attributes that can be considered minutiae. Use of scars as a search criteria will require search and match algorithms, as well as operational procedure, to account for the potential absence of the scar in a previous record in the data base.

2e Crease

Crease – a linear depression or grooves in the skin which can appear as a white line (ridge absence) in a fingerprint impression: grooves at the joints of the phalanges, at the junction of the digits and across the palmar and plantar surfaces that accommodate flexion. Creases within friction ridged area can be permanent and non-permanent. Flexure creases between major fields of friction ridge skin are permanent and provide unique configurations of features. The flexure creases will provide "feathering" which provides both location and direction to each aspect of the crease.

2f Incipient ridge

Incipient ridge(s) – a friction ridge not fully developed which may appear shorter and thinner in appearance than fully developed friction ridges.

2g Dot

Dot – an isolated ridge unit whose length approximates its width in size. Direction of this feature is immaterial. Just use it!

3 Level 3 Detail

3a Pores

Pores – a small opening on friction ridges through which body fluids are released. The relationship of a series of pores on a single ridge and those relationships with adjacent ridges should be considered. Ridge path must be determined first and the pores linked to that ridge. (Plain impressions and non-contact captured images may provide more accuracy in the detection process)

3b Edge shapes

Edge shapes – morphological features (width, major deviation, etc.) defining the contour or shape of the ridge edge.

3c Ridge/furrow width

Ridge/furrow width – the measurement from edge-to-edge of a ridge and edge-to-edge of a furrow; center of ridge to center of adjacent ridge.

3d Feature relationship

Feature relationship – the aggregate of all of the above.