The GYRO System — A Recommended Approach to More Transparent Documentation

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In a movement towards greater documentation in the fingerprint discipline, mostly promulgated by critical commentators [1, 2, 3], legal cases [4, 5], and the National Research Council (National Academies of Sciences) report on forensic science [6], SWGFAST has created a standard for documentation in fingerprint casework [7]. This standard states:

> When friction ridge detail is examined using the ACE-V methodology, examiners' documentation shall be such that another qualified examiner can determine what was done and interpret the data. Documentation shall be made at or near the time of the examination and may be in the form of annotated images, narratives, worksheets, annotated legible copies, sketches, [etc.]…Although all examinations require documentation, the extent of the documentation is related to the complexity of the examination. The friction ridge impression alone is not sufficient documentation. The impression or a legible copy shall be annotated or have accompanying notes (p.1, preamble)

An analyst can meet this standard by marking dots for minutiae, tracing ridges, or as some older practices advocate: using a ridge counter to puncture holes in photographs or dimple the photograph to indicate where the analyst was comparing features [8]. These documentation styles can easily be incorporated into the ACE-V[1] process. However if analysts are strictly following the ACE-V protocol, one could expect to see features annotated in the latent print during the analysis (before observing the exemplar print), features annotated that were compared against the exemplar print, and then another set of features annotated for the analysis and comparison performed by the verifier.

A limitation of these forms of documentation is that it does not convey what weight is being assigned to these features during the analysis and comparison. Furthermore it is not showing if the analyst is equally confident in all the features annotated during the analysis.

This paper puts forward a system that meets the minimum requirements of SWGFAST, and adds further information and transparency to the documentation. Most specifically, the proposed annotation system conveys information regarding weighting of the features and the level of confidence attached to the feature by the analyst.

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[1] An acronym for the generic protocol followed by fingerprint analysts. The acronym stands for Analysis-Comparison-Evaluation-Verification. See *Friction Ridge Examination Methodology for Latent Print Examiners* (August 22, 2002, v.1.01) at www.swgfast.org for a more detailed description.

The proposed system is called the GYRO system, where GYRO is an acronym for Green-Yellow-Red-Orange. GYRO has been used in training courses now since 2005 [9]. Scores of analysts attending the courses have communicated to the authors their approval of the system, and many (albeit informally) have adopted its use within their actual casework. This paper shares the value of the GYRO system (or any analogous annotation system) and the authors hope that more analysts will utilize such an approach.

GYRO Basics

The primary benefit of GYRO is not just to communicate which features have been selected during the Analysis phase, but also to document the analyst's: 1) level of certainty regarding the existence of the feature, 2) the amount of weight the analyst will assign to the feature during the Comparison phase, 3) the expectation that the feature ***will be present*** in an exemplar ***if the exemplar and latent print were produced by the same area of friction ridge skin***, 4) the tolerance[2] that has been assigned for that feature. This is useful additional information which can be conveyed to a case reviewer, and it can be accomplished by using a simple color scheme: green, yellow, red, and orange colors.

An analyst should mark a feature with green when he or she is highly confident in the existence of the feature in the latent print. A green feature will then accordingly be given more weight during the Comparison phase, the analyst will have a high expectation to see the green feature in the Comparison phase, and the analyst's tolerance for how that feature will appear (its position, shape, type, etc.) will be low. In other words, that green feature must appear in the known print (if the exemplar and latent print were produced by the same area of friction ridge skin) and the amount of acceptable distortion for that feature will be fairly low.

An analyst should mark a feature with yellow when he or she has a medium level of confidence in the existence of the feature in the latent print. A yellow feature accordingly will have medium weight during the Comparison phase, the analyst will have a medium level of expectation to see the feature, and a medium level of tolerance assigned to the feature.

An analyst should mark a feature with red when he or she has a great deal of uncertainty regarding the feature and has a very low level of confidence in the existence of the feature in the latent print and high tolerance for how the feature will appear in the exemplar. Red features should be given minimal weight during the Comparison phase (even if they do exist in correspondence between the latent print and known print). This is because of the significant uncertainty the analyst possessed regarding the presence of this feature and the increased range of tolerance that was allowed for this feature. This uncertainty[3] should be carried into the Comparison phase and can be represented during the weighting of this feature. Uncertainty does not disappear when examining a known exemplar in fingerprint examinations; it is carried

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[2] Tolerance can be defined as the analyst's assessment of how willing he or she is to accept differences in appearance due to distortions when the feature in the latent print is compared to a corresponding feature in the known print [10, 11].

[3] Analysts should think of this term "uncertainty" more akin to the concepts of measurement error and precision.

through the entire inductive process. Figure 1 represents an image annotated using GYRO during the Analysis phase.
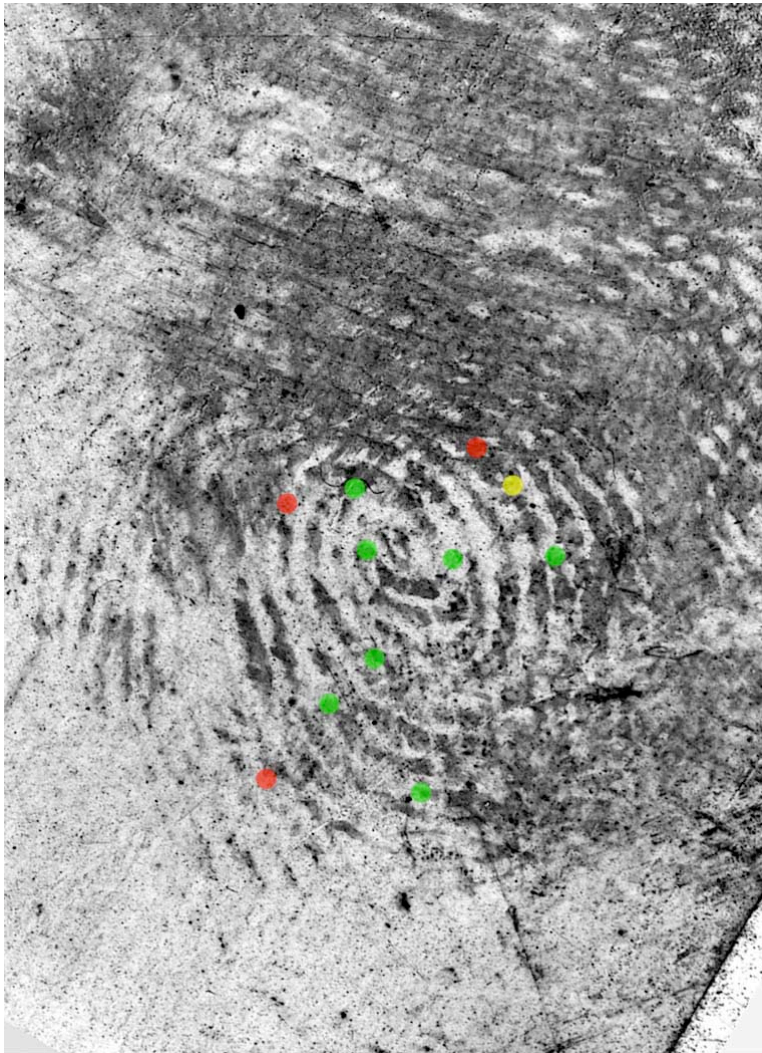

Figure 1: A complex latent print that has been annotated by a fingerprint analyst in the Analysis phase (without the presence of an exemplar print) using GYRO.

Lastly, the color orange is used to represent features that were not observed initially in the Analysis phase, but rather, were observed in the Comparison phase, while using the exemplar print to "see" the feature in the latent print. Some commentators have rightly raised the issue of using the exemplar print (typically of a higher quality) to find features in the latent print (typically of a lower quality and can be highly distorted). These commentators have raised the issue of circular reasoning and the dangers of confirmation bias [12-15]. On the one hand, Haber and Haber [16] have gone so far as to state that bias will occur (making an erroneous identification more likely) if the exemplar is used. On the other hand, some commentators have supported the practice of using the exemplar, but have noted the dangers of cognitive bias [11, 18]. The GYRO system offers a compromise between these two camps: the analyst may use the feature observed only after examining the known print, but the analyst must be transparent about when it was first observed.

The use of the color orange (in the authors' opinion) is also appropriate since it is a fair (but intuitive) approximation of the weight that can be assigned to the feature. This weight can be higher than a red feature, but should be lower than a yellow feature (the primary colors yellow and red combine to make orange). Figure 2 shows GYRO markings in the Comparison phase.
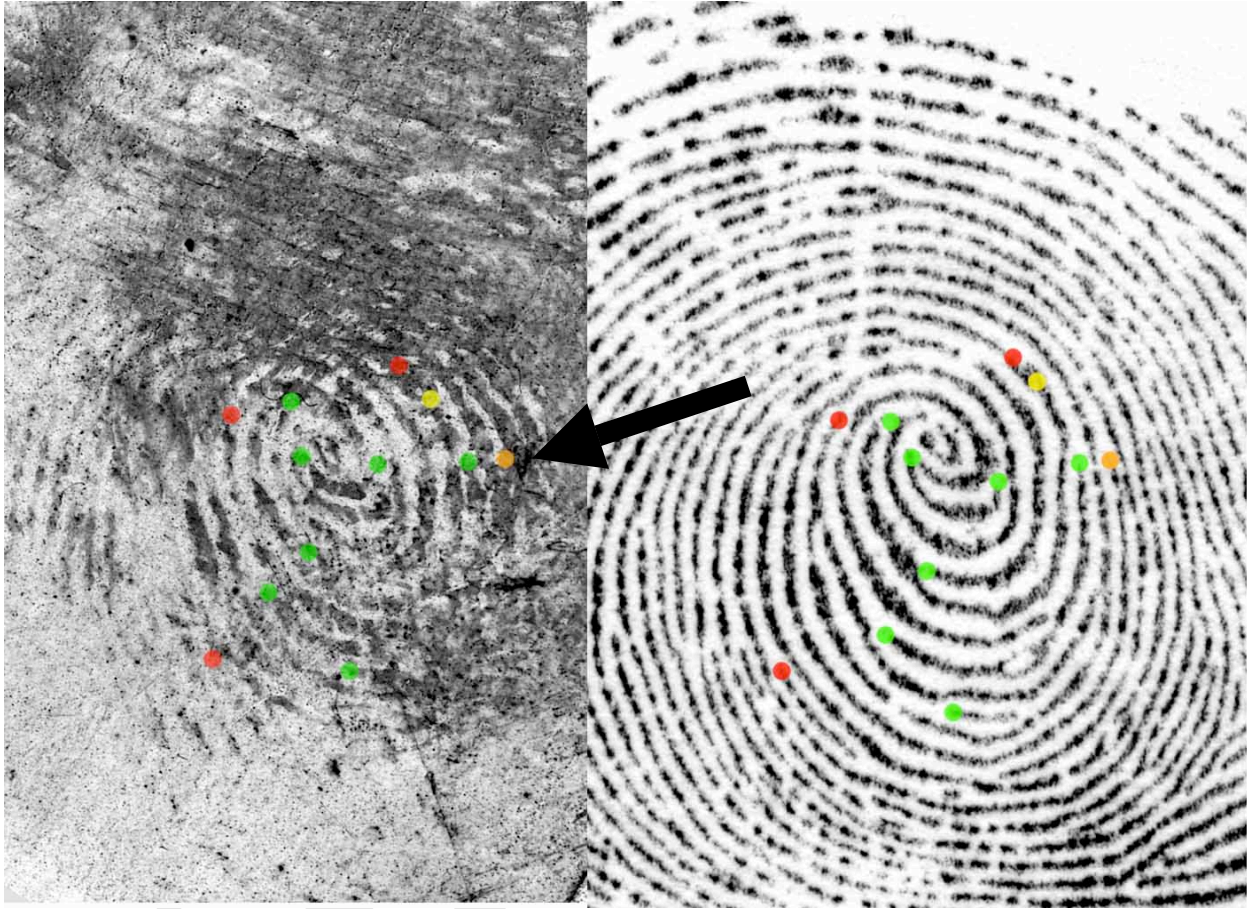

Figure 2: The latent print from Figure 1 has now been compared against an exemplar. The corresponding features are marked in the exemplar using corresponding colors. Orange features (indicated by the arrow) represent features observed during the Comparison phase and only after observing the exemplar print.

Also, it should be noted in Figure 2 that when marking the known print, the colors used for the corresponding mated features represent the colors of the features in the *latent print*. It has been observed in training courses, that some students have preferred marking the known print to also represent the uncertainty of the features in the known print. This choice is left to the reader, but initially this GYRO system was conceived to represent a system of conveying uncertainty for the latent print, since ideally, the analyst should request better exemplars if they are of such poor quality that the examination is hindered.

Of course, any color scheme can be chosen for preference. Some students raised concerns to the author that due to color blindness, they would prefer to use different colors. The GYR colors were chosen arbitrarily because they fit the colors of a semaphore traffic light (green = go,

yellow = caution, red = stop) and because with orange, they made a nice acronym. The color choice is irrelevant as long as the analyst declares the meaning associated to the color.

Actual implementation of GYRO is most easily achieved using Adobe Photoshop software. Layers can be created during the Analysis and Comparison phases. On each layer, the analyst can annotate features, changing the color of the brush and using the color palette. In training courses, students are instructed to use permanent markers to annotate images under an acetate sheet. Whether done manually on a photograph or in a digital environment, this documentation should be included within the case record for a reviewing analyst or technical reviewer.

PiAnoS — A Picture Annotation System

A team of researchers (J. Furrer, R. Voisard, T. Genessay and C. Champod) at the University of Lausanne in Switzerland developed a software called PiAnoS (A Picture Annotation System) as a generic interface to annotate and conduct forensic comparison work separating the analysis from the comparison phase[4]. This software allows for documentation of images in cases following the ACE-V protocol. During the Analysis phase, images of the latent print are first presented to the analysts, whereby the analyst selects and annotates the features to be used during the Comparison phase. Once the features are selected, they are permanently saved and the exemplar print is presented to the analyst for comparison. There is no way to alter the documentation of the Analysis phase once the user has moved into the Comparison phase. These annotations remain a permanent record of the features and conclusions reached during that phase. The analyst can then annotate features in correspondence between the images and give its evaluation. PiAnoS will track any changes made to annotations on the latent print during the Comparison phase, including the addition of new minutiae added after viewing the exemplar.

A number of similarities exist between PiAnoS and GYRO. First, both offer the analyst an opportunity to select an associated level of confidence for each feature that is selected. Second, neither tool is strictly limited to annotating only minutiae. One can use PiAnoS or GYRO to trace the ridges, creases, scars, etc. Third, features selected during the Comparison phase appear in PiAnoS as a different color than those selected during the Analysis phase.

A significant advantage of PiAnoS is the "tutor" mode. In this mode, a course instructor can display simultaneously (or select specific users for display) all of the annotations made by students in a classroom setting. This information can be shown to a classroom and discussion regarding the decisions and precision/accuracy of annotations can occur (see Figure 3). By using anonymous log-ins for students, all of the students' results can be viewed simultaneous, providing critical feedback to the students, without singling out any one student that may be embarrassed or pressured by the environment. This sort of complex feedback cannot easily and quickly be done with GYRO.

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[4] PiAnoS is an open-source development freely available from the Ecole des Science Criminelles, University of Lausanne (Prof. C. Champod).
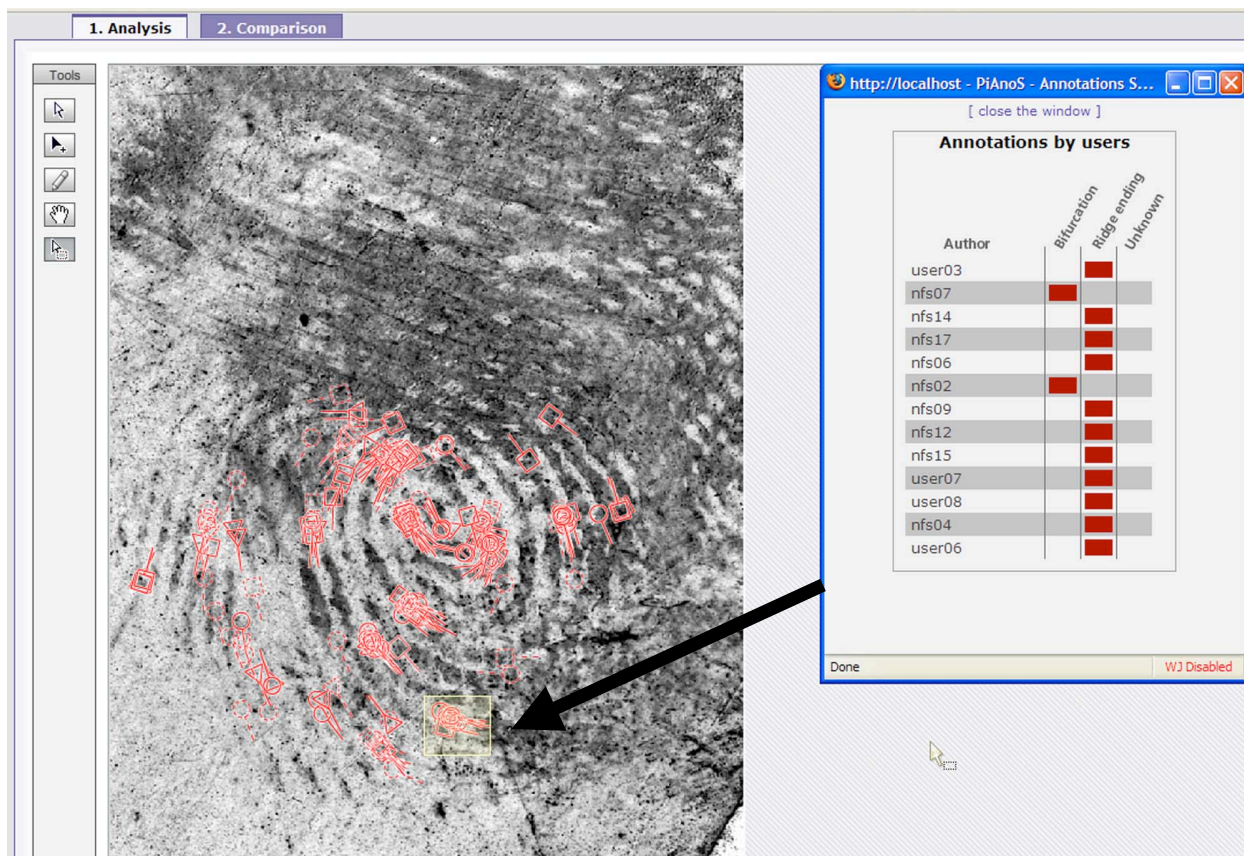
Figure 3: The "tutor" view from PiAnoS showing all the users' annotations and decisions simultaneously (with the option to select any one user and see his/her results). The insert on the right side of the screen displays the users that have annotated the minutia indicated by the arrow.

One can envision using PiAnoS for other purposes besides training and casework. Other uses may include an environment for blind testing or proficiency testing, "complex case" discussions among analysts in a latent print unit, or collecting data during research, since the information for participants can be recorded anonymously, and data for large pools of analysts can be extracted and analyzed. Currently, such research efforts are underway [19].

Validity of GYRO

A fair question of GYRO is to ask the following: Do the levels of certainty, expectation, and analyst confidence reflect a genuine reality? In other words, if an analyst marks a green feature, is he or she actually more likely to be correct that the feature exists? Control trials of GYRO were undertaken.

Enlarged photographs of the latent prints (designated as latent prints/fingermarks "LP 6-5" and "LP 6-6") were given during training classes attended by trained analysts (N = 24, N = 25 for each fingermark respectively). All of the analysts had over two years experience and were working fingerprint cases in government agencies in the United States. The analysts were taught the GYRO method and asked to annotate the minutiae in the two images using GYRO in the

Analysis phase. LP 6-5 represented (by consensus) a complex case and LP 6-6 represented (by consensus) a medium to low complexity case (see Figure 4). Table 1 shows the associated error rates for the GYRO markings for these two latent prints. The error rates were determined based on the ground truth for the minutiae, using the known friction ridge skin source. Annotations in the latent print that corresponded to actual minutiae in the source skin were scored as "correct"; annotations that did not correspond to actual minutiae were scored as "false". For a small portion of annotations, the markings were too ambiguously placed to tell if the analyst was marking the minutiae correctly. These annotations were scored as "indeterminate".

LP 6-5   LP 6-6

Figure 4: The latent print on the left is designated as LP 6-5. This is a complex fingermark and has a number of severe distortions with limited quantity and quality of features available. The latent print on the right is designated as LP 6-6. This is a medium (to low) complexity fingermark with some distortions, but relatively high quality and quantity of features available.

LP 6-5	Mean Number of Minutiae Marked (Std Dev)	GYRO Colors	Number Minutiae Marked	% of Markings by Color	% Correct	% Indeter-minate	% False
U.S. Training Class N = 24	12.4 (5.01)	Green Yellow Red	150 96 52	50% 32% 18%	87% 71% 58%	2% 1% 2%	11% 28% 40%
		Total	298		75%	2%	23%
LP 6-6							
U.S. Training Class N = 25	20.2 (4.89)	Green Yellow Red	364 105 37	72% 21% 7%	99+% 86% 73%	0% 0% 0%	<1% 14% 27%
		Total	506		95%	0%	5%

Table 1: Error rates for GYRO markings during the analysis of LP 6-5 and LP 6-6.

The data in Table 1 show three important trends. First, as evidenced in other studies [12, 20-21], significant variation amongst analysts can occur when selecting features. The percent relative standard deviation (%RSD[5]), is a statistic for normalizing and comparing variation. For LP 6-5 the %RSD is 40.4% and for LP 6-6 the %RSD is 24.2%. Therefore the analysts were more precise (had less variation) marking the easier latent print than marking the complex latent print. Second the error rates for each GYRO color directly correlated to the analysts' assignment of confidence. The features the analysts were most confident existed (green) had the lowest error rates; conversely, the features the analysts were least confident existed (red) had the highest error rates. Finally, the error rates for the complex latent print (LP 6-5) are higher than the error rates for the low complexity case (LP 6-6). Further study on this issue will likely show that error rates for minutiae selection and examiner consistency will be highly dependent on the quantity and quality of ridge detail available in the latent print. However, it was demonstrated in these trials, that the analysts' subjective assignment of certainty using GYRO did reflect the accuracy of the annotations.

Summary

Especially when dealing with complex cases, the authors strongly recommend using a more detailed annotation system like GYRO. Conveying levels of certainty, weights of features, and tolerances of the analyst are helpful contributions to the transparency of documenting the ACE-V decision making process. In cases where variation in analyst opinions can commonly occur, it becomes critical to understand how analysts reach conclusions. GYRO or any similar annotation system (such as PiAnoS) provides a mechanism for enhanced transparency and additional information is easily conveyed to a reviewing analyst.

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[5] Relative standard deviation, as a percent, is calculated by dividing the standard deviation by the mean, and multiplying by 100%.

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