

# LatentSleuth: An Emerging Latent Print Automated Searching Technology – A Validation Study

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**Abstract:** Sciometrics LatentSleuth technology uses a ridge skeleton-matching algorithm to automate latent print searching. Incorporating all usable information within a latent print, rather than only minutiae as in traditional approaches, enables more challenging latent prints to be searched. Proprietary technology creates an overlay of the ridge geometry based on continuous short segments of ridges or furrows detected in both the latent and reference prints while adjusting for distortion in both. Accuracy of the overlays is determined, and a prioritized list is created. Prints that are distorted, prints that contain discontinuous ridges, prints that are of an unknown orientation, and prints containing limited minutia points may be searched.

Six hundred searches were conducted using 200 latent prints with true-mated reference prints. Latent print quality and comparison complexity (determined by the number of exemplars) were evaluated. Fifty latent prints of 4 different quality levels were searched against groups consisting of 3, 5, or 10 sets of reference images. Overall accuracy for high, medium high, medium low, and low latent prints was 98%, 95.3%, 98.7%, and 86.7%, respectively. Results were considered accurate if the true-mated reference image was one of the first five candidates on the prioritized list. The LatentSleuth software provided accurate results in all latent print quality levels against all evaluated levels of comparison complexity and was deemed suitable for use in casework. Implementation in casework may assist in limiting examiner fatigue, the identification of more challenging prints, and reducing case turnaround time by improving the efficiency of the comparison workflow process.

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## Introduction

Analysis, comparison, evaluation, and verification (ACE-V) methodology is the standard examination process used by the latent print discipline [1]. Analysis is the assessment of information present within a latent print to determine whether it is of value for comparison. Comparison is the side-by-side observation of two impressions to determine agreement or disagreement based on examining similarities, dissimilarities, or differences in the ridge features. An evaluation of the similarities and dissimilarities present in the latent and the known print is performed to render a conclusion. Accepted conclusions are identification (sufficient similarity in agreement is present to determine that the two impressions originated from the same source), exclusion (sufficient disagreement exists to determine that the impressions did not come from the same source), or inconclusive (there is not enough information, either in one impression or both impressions, such that a decision of identification or exclusion cannot be made). Lastly, another qualified examiner independently completes his or her own analysis, comparison, and evaluation, fulfilling the verification step.

Traditional manual searching methods conducted by an examiner can be arduous, depending on the quality of a latent print. Typically, an examiner identifies a distinct set of features (target group) and searches for similar correspondence in another impression [2–4]. For lower quality latent prints, this can be time consuming. Latent prints lacking anatomical aspect can require an exhaustive search of all areas of friction ridge skin of the fingers, lower joints, and palms. In addition, latent prints lacking orientation information may require numerous searches of all areas of friction ridge skin with different positioning of the latent print.

Incorporating an automated searching program into manual comparison workflow may assist in improving accuracy and efficiency of casework by focusing examiner efforts more on comparisons instead of searching. LatentSleuth (Sciometrics, LLC., Chantilly, VA) technology produces an overlay of a latent print created from ridge segments to automate searching, incorporating all usable information in a latent print as opposed to feature-only based approaches seen in traditional automated searching systems. The use of ridge geometry allows for automated searches of more challenging, low quality latent prints with limited clear features, unknown orientations, or distortion.

### *LatentSleuth Software Functionality*

The LatentSleuth software functions as a tool to assist the latent print examiner in locating potential correspondence between a latent print and a reference print [5]. Basic steps include importing and processing the latent image overlay, selecting a quality region of interest, uploading reference images, and reviewing the generated prioritized list (Figures 1–4).

Automatic processing of a latent print image includes creating a high-contrast overlay image based on ridgelines prepared from the short segments of the ridges. A quality map is produced, which masks areas of limited quality ridge flow and prevents those areas from being included in the search. The quality maps generated by the software produce levels of varying degrees (i.e., differences in quality map opacity relate to the amounts of masking of areas) (Figure 5). Levels range from highly transparent opacity (limited masking of ridge detail) to no transparency (total masking of detail). Both the quality map and ridgeline overlay can be edited and further processed by the examiner. When manual processing of the quality map is performed, no levels of masking are available. An area is either masked, which excludes it from the search, or it is not masked, which includes the area in the search. Finally, the examiner manually selects a quality region (or multiple regions), which is the area from which the overlay is created.

Reference images are imported into the LatentSleuth software and a template is applied. Templates can be created allowing for importation of all forms of exemplars (e.g., standard applicant cards, AFIS-generated cards, etc.). Groups of reference images may be created and saved for use in multiple cases or searches. The template consists of individual boxes allowing for each finger in the reference image to be individually searched as a separate file. A standard tenprint card will yield 14 files and 14 search results: 10 rolled fingers, right and left plain impressions, and right and left plain thumb impressions. Reference images are subjected to automated processing as well, including developing a high-contrast image overlay, as well as applying a quality map. A search (referred to as “recognition” or “run” by the software) containing the latent image(s) and reference images is conducted. Multiple searches can be queued and submitted to run consecutively at a later time (e.g., overnight).

Upon completion of a search, a prioritized list is generated; the highest score is the reference image with the most consistent correspondence to the latent print overlay and will rank at the top of the list. Reference images are presented with the latent print ridge structure overlay on top of it in the proper orientation, clearly displaying correspondence or lack of correspondence.

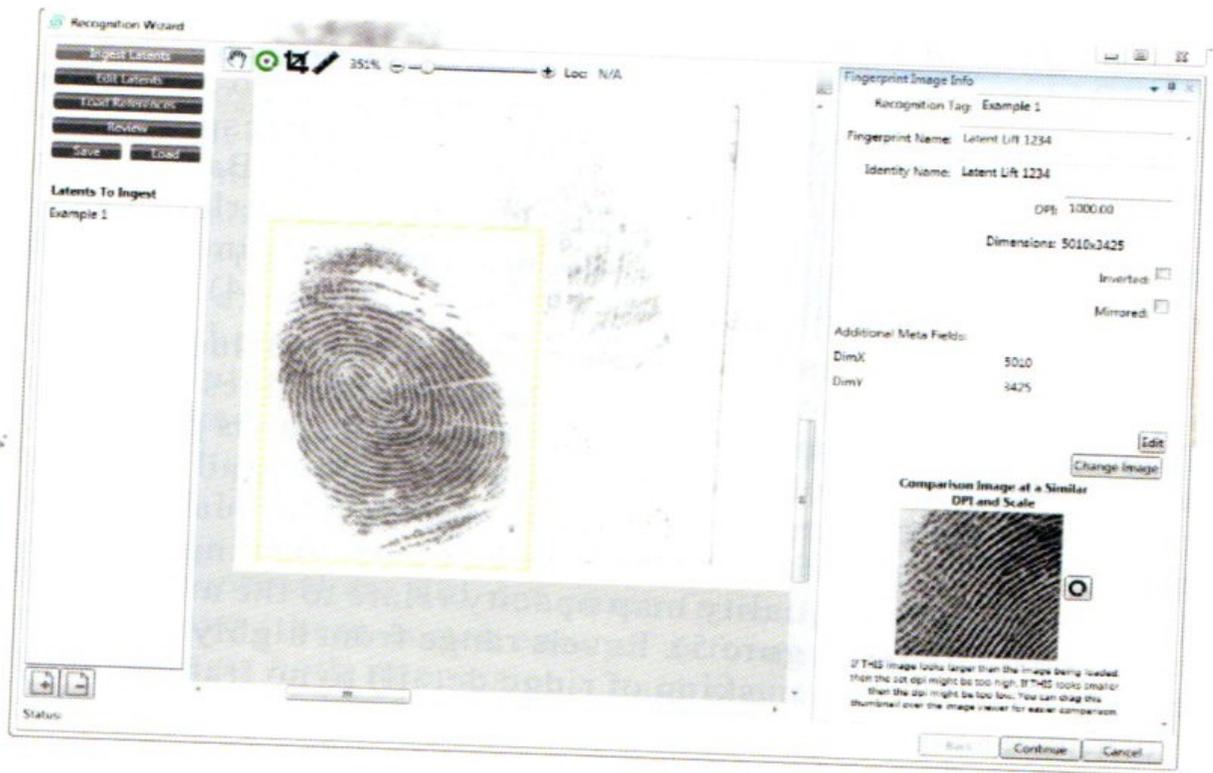


Figure 1  
Imported latent print.



Figure 2  
Processed latent print with selected quality region.

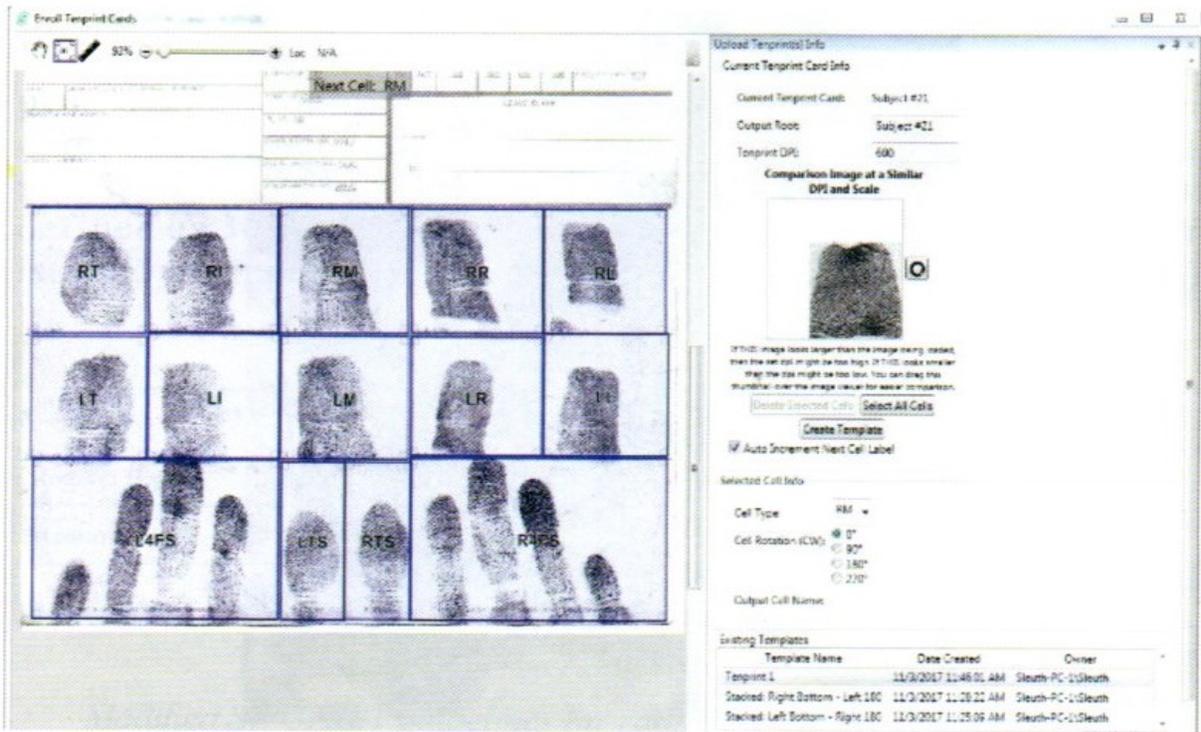


Figure 3  
Applied template to reference file.

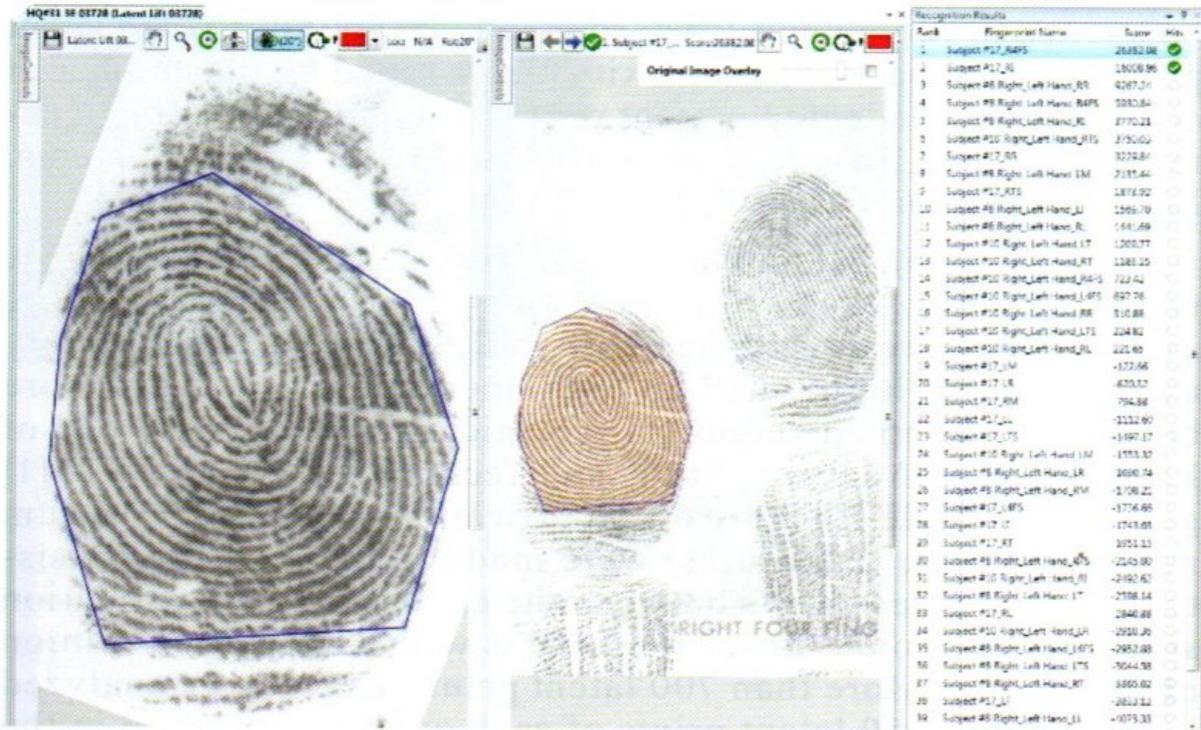
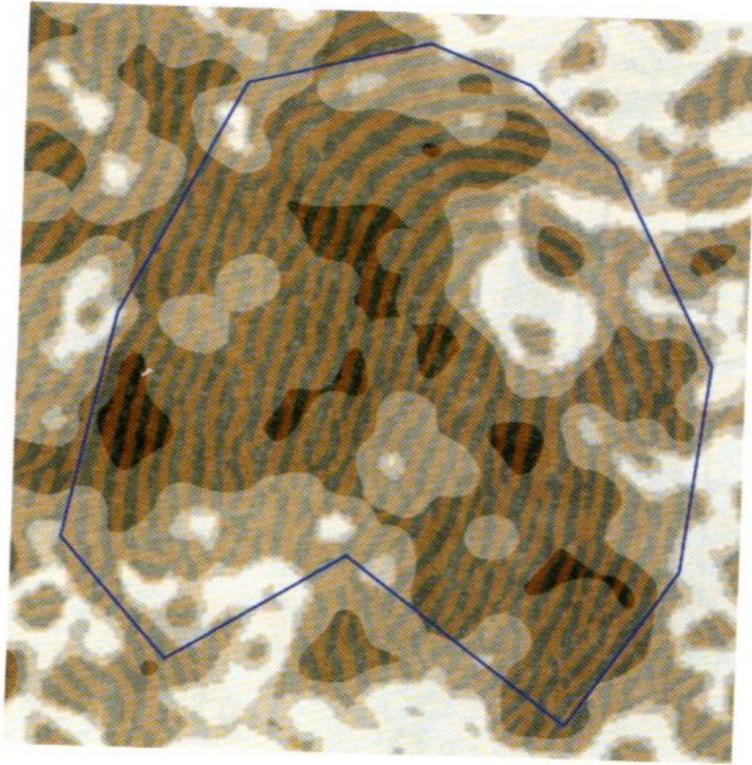


Figure 4  
Review view.



*Figure 5*

*Quality map with varying levels of masking.*

### **Materials and Methods**

Accuracy of the LatentSleuth software was evaluated based on latent print complexity, determined by the quality of the latent print, and comparison complexity, determined by the number of comparisons conducted. Latent prints, with corresponding true-mate reference images, were purchased from Mideo Systems, Inc. (Huntington Beach, CA).

To ensure consistent characterization of latent print quality, two examiners, each with more than 15 years of experience, independently evaluated the quality of each latent print. Quality assessments of high, medium high, medium low, and low were based on an adapted version of the Scientific Working Group of Friction Ridge Analysis, Study and Technology (SWGFAST) [1] guidelines (Table 1, Figure 6). Modifications (adding a minimum number of Level 2 features) were made to improve the consistency of the assessments between the examiners. The validation study included only those latent prints with a consensus opinion of the quality. More than 700 latent print images were analyzed independently; 50 latent prints of each quality were used in the validation. The validation included only fingerprints; joints and palm prints were not included in the research.

Comparison complexity was stratified into three categories: low, medium, and high. A comparison was defined as one latent print searched against one reference print (e.g., one latent print compared against one tenprint exemplar equaled 10 comparisons). For this validation, low comparison complexity was defined as 30 comparisons (3 exemplars), medium as 50 comparisons (5 exemplars), and high as 100 comparisons (10 exemplars).

Latent Print Quality Guidelines	
High	Level 1 is distinct, little or no distortion present; numerous distinct Level 2 details and abundant, clear Level 3 detail evident.
Medium High	Level 1 is distinct, may be slightly distorted; at least twelve distinct Level 2 details and minimal visible Level 3 detail evident.
Medium Low	Level 1 is distinct, distorted; at least nine distinct Level 2 details of varying clarity visible and Level 3 detail is hard to distinguish.
Low	Level 1 may not be distinct; heavily distorted; at least seven distinct Level 2 details, may be difficult to determine and no Level 3 detail is evident.

Table 1  
Modified SWGFAST guidelines for rating the quality of a latent print.

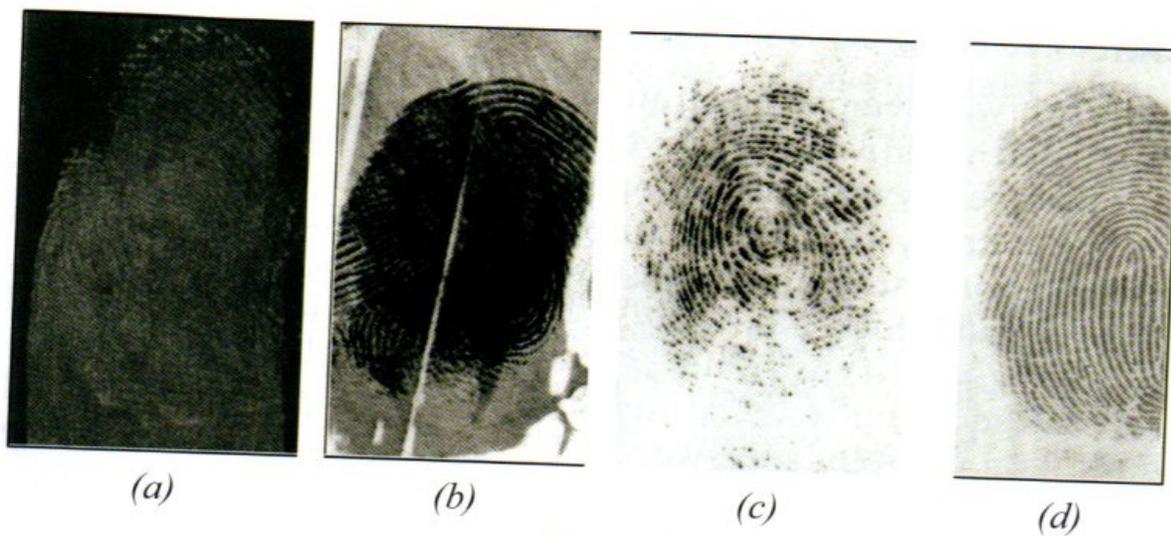


Figure 6  
Examples of latent print qualities: (a) low; (b) medium low; (c) medium high; (d) high.

## *Validation*

Latent print and corresponding true-mate reference print images were exported from a software training program (TrainingWorks, Mideo Inc.) and imported into the LatentSleuth software at 1000 pixels per inch. Six hundred LatentSleuth searches were conducted: 50 latent prints of each quality level were searched against each comparison complexity.

Initially, only automatic processing by the software was used on the latent prints. Preliminary results indicated manual processing of medium low and low quality latent prints was necessary, which is recommended in the LatentSleuth operation manual. Manual processing, including altering the quality map and correcting ridge skeletons, was conducted on each medium low and low quality latent print; the results for both searches were recorded. A trained<sup>1</sup> technician conducted data collection, including importation of all images, selection of the quality region, manual processing of the latent prints, and review of results against ground truth. An experienced examiner reviewed the results as necessary.

## **Results**

A result was deemed accurate if the true-mate reference image was located within the top five positions of the prioritized list and if the overlay was located on the correct corresponding ridge detail. Accuracy results for automated processed latent prints across all comparison complexities were 98.0% (high quality), 97.3% (medium high quality), 70.7 % (medium low quality), and 52.0% (low quality) (Table 2). Accuracy results for manually processed medium low and low quality latent prints across all comparison complexities were 98.7% and 86.7%, respectively (Table 2).

## **Discussion**

A result was considered nonaccurate if the overlay was located on the correct corresponding ridge detail, but the true-mate reference print was outside of the top five positions on the prioritized list. Further, nonaccurate results included nonhits, which were if the overlay was not placed on the correct corresponding ridge detail of the true-mate reference print, independent of its location on the list.

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<sup>1</sup> A part-time grant-funded employee was trained in the operation of LatentSleuth by the authors to assist in data collection for the validation.

		Quality of Latent Print					
		High	Medium High	Medium Low		Low	
		Automated	Automated	Automated	Manual Processing	Automated	Manual Processing
Comparison Complexity	Low	49/50 98%	49/50 98%	37/50 74%	50/50 100%	28/50 56%	44/50 88%
	Medium	49/50 98%	49/50 98%	35/50 70%	50/50 100%	26/50 52%	44/50 88%
	High	49/50 98%	48/50 96%	34/50 68%	48/50 96%	24/50 48%	42/50 84%
Overall Accuracy		<b>98.0%</b>	<b>97.3%</b>	<b>70.7%</b>	<b>98.7%</b>	<b>52.0%</b>	<b>86.7%</b>

Table 2

Accuracy results (number of hits/number of searches, percentage) of automated and manual processing.

### High Quality Latent Print Images

With automated processing, the true-mate reference prints ranked in the number one position of the prioritized list in 98.0% of the searches. A nonhit result was recorded for one high quality latent print in all comparison complexity searches (Figure 7). The exemplar was of poorer quality and the software failed to accurately detect and trace two clear short ridges near the delta. These ridges were present in both the rolled and plain reference prints; however, the area to the right of the delta was missing in the plain print.

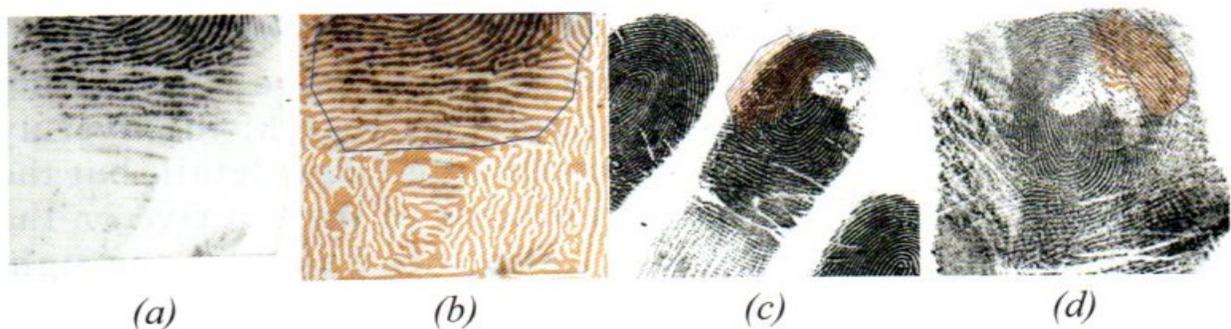


Figure 7

Nonhit high quality latent print: (a) latent print; (b) automated processed image; (c) overlay on true-mate reference print plain impression, on incorrect area of correspondence (#6 on prioritized list); (d) overlay on true-mate reference rolled impression, on incorrect area of correspondence (#20 on prioritized list).

### *Medium High Quality Latent Print Images*

With automated processing, the true-mate reference prints ranked within the top five of the prioritized list in 97.3% of the searches and in the number one position of the prioritized list for 92% of the searches.

One latent print (Figure 8) produced nonhit results when searched across all comparison complexities; the software did not find the true-mate corresponding ridge detail. In this latent print, the contrast was low and there was background interference. Enhancement of the image prior to processing might have eliminated those issues.

One latent print search (Figure 9) produced a nonaccurate result (sixth on the prioritized list) only in the high comparison complexity search. In the low and medium complexity comparison searches, the true-mate reference print was third and fifth on the prioritized list, respectively. The clearest area of ridge was located in the delta area. Deltas, being pattern-forced areas, contain details that lack specificity. Adding more exemplars to the search against latent prints with less specific details appeared to have an effect on the results.

### *Medium Low Quality Latent Print Images*

Manually processed medium low latent print images produced an overall accuracy of 98.7% when searched (Table 2). Of those accurate results, 94% were in the number one position on the prioritized list, regardless of comparison complexity (Table 3).

The results for two latent print searches were nonaccurate only in the high comparison complexity search; the overlay was located on the correct corresponding ridge detail, but the true-mated reference image was outside of the top five on the prioritized list. One of these latent prints was from the right side of a left slope loop pattern in the area below and to the upper right of the core. In the high comparison complexity search, the true-mate reference image was located in the twelfth position, down from the second and third positions in the low and medium comparison complexity searches, respectively. The latent print was composed of a large open field area with nonspecific ridge flow; only in the high complexity comparison search (100 comparisons) was the software unable to produce accurate results. In the second medium low latent print, heavy, uneven pressure caused thick ridges. The true-mated reference print dropped to the seventh location from the first and third positions in the low and medium comparison complexity searches, produc-

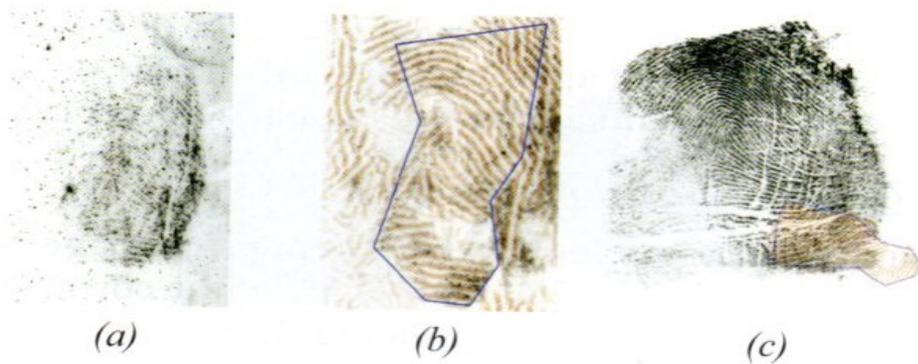


Figure 8

Medium high quality latent print producing nonhit results: (a) original image; (b) automated processed image; (c) overlay on true-mate reference image on incorrect area of correspondence (#10 on prioritized list).

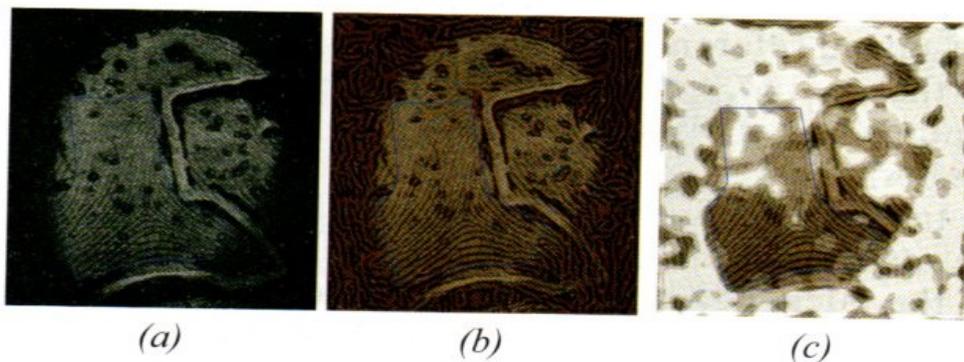


Figure 9

Medium high quality image: (a) original image with quality region; (b) automated processed image; (c) automated processed image showing quality map.

		Quality of Latent Print			
		Medium Low		Low	
		Accurate Results	#1 Candidate	Accurate Results	#1 Candidate
Comparison Complexity	Low	50/50 100%	48/50 96%	44/50 88%	41/50 82%
	Medium	50/50 100%	47/50 94%	44/50 88%	35/50 70%
	High	48/50 96%	46/50 92%	42/50 84%	31/50 62%
Overall Accuracy		<b>98.7%</b>	<b>94%</b>	<b>86.7%</b>	<b>71.3%</b>

Table 3

Accuracy results (number of hits/number of searches, percentage) for candidates in the number one position in results for Medium Low and Low manually processed searches.

ing the nonaccurate result. One ridge above the core was difficult to decipher and was not appropriately traced. The missing ridge only affected the results in the high comparison complexity.

### *Low Quality Latent Print Images*

Manually processed low quality latent print images produced an overall accuracy of 86.7%, with 71.3% of the correct reference images in the number one position (Table 3).

For one latent print (Figure 10), accuracy increased with the addition of two exemplars; the true-mate reference image moved from the fifth position on the prioritized list in the low comparison search to the fourth position in the medium comparison search. However, in the high comparison complexity search, the true-mated reference image dropped to the twelfth position. Likely, the qualities of both the latent print and the reference image played a role in the nonaccurate result. The latent print was a whorl lacking clarity and contrast on a textured surface, and the true-mate reference image was slightly distorted and was lacking some areas of correspondence. Furthermore, the clearest area of the latent print, above the core and in the tip area, was not fully represented in the exemplar. With the addition of more reference images, the qualities of the latent print and reference images had more impact on the ability of the software to provide accurate results; accurate results were only affected in the high comparison complexity despite the lack of tip area present in the true-mate reference.

Two low quality latent prints produced nonhit results (the software did not find the correct corresponding ridge detail) when searched against all levels of comparison complexities. Corresponding areas for both prints were not fully recorded in the true-mate reference (Figure 11). Quality control checks were not performed on the latent prints prior to use in the study; manual comparison after the fact revealed that there was not sufficient information present in the true-mated reference image to make a conclusion of identification. Knowing ground truth does not mean identification is always an appropriate conclusion. Hence, in retrospect, these two latent prints should not have been used in the study. It is unreasonable to expect the software to locate the correct corresponding ridge deal when it is not sufficiently recorded.

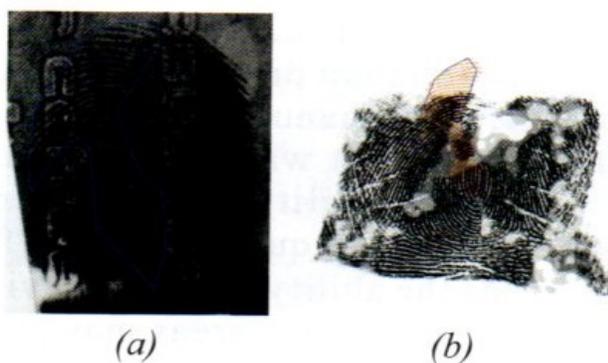


Figure 10

*Low quality latent print. Place 5, 4, 12 for low, medium, and high comparisons, respectively: (a) original image with quality region; (b) overlay on true-mate reference image.*

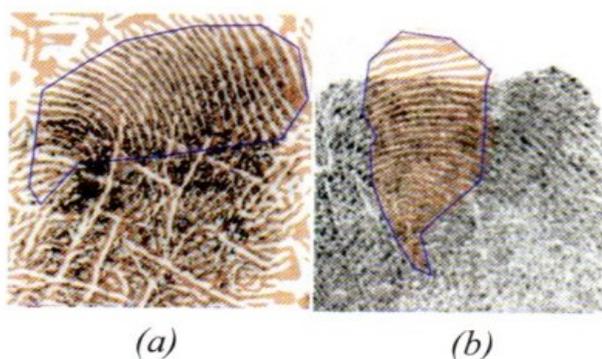


Figure 11

*Low quality print producing nonhit results: (a) edited latent print; (b) overlay on true-mate reference image on incorrect correspondence.*

With manual processing, two additional low quality latent prints produced poorer results. The first latent print was smudged, with limited clear detail above the core. With automated processing, accurate results were obtained in the low and medium low comparison complexities; nonaccurate results were only in the high comparison complexity search. However, after manual processing, the latent print produced nonaccurate results in all categories. Manual processing included deleting, retracing, and connecting ridges through areas of distortion in addition to eliminating the quality map. After manual processing, the true-mated reference image moved from second to fifteenth on the prioritized list in the low comparison complexity search, from third to twenty-fourth in the medium complexity search, and from ninth to fifty-eighth in the high complexity search. It was determined that too much editing in areas of unclear detail can have a negative effect; better results are obtained if heavily distorted areas are masked and not considered in the search (Figure 12).

Accurate results across all comparison complexities were achieved with the second latent print after automatic processing (Figure 13). However, after manual processing, all results were nonaccurate. The latent print was a large double loop whorl. Approximately the same quality regions were used in both searches; however, the level of quality maps differed. As stated earlier, the software has the ability to place varying quality levels within the quality map, thus some areas may still be considered in the search but at a lower level. In manual processing, there is only one level of quality mask (i.e., either an area is masked and not included in the search, or it is not masked and the area is included). For this latent print, the automated processed image quality map included a large portion of the latent print with at least some level of masking (Figure 13a), meaning the ridges in that area were still considered in the search at a lower level, whereas after manual processing of the quality map, areas that were masked were fully excluded from the search (Figure 13b). Further, it should be noted that a quality map was also automatically applied to the reference image, thus masking out areas of less clear detail. Areas were masked in the reference image that were in the corresponding area of the latent print image. The latent print was searched again at low comparison complexity only using a smaller quality region consisting of one section of the recurve in the double loop whorl with only a small portion masked. The true-mated reference image, with the overlay on the correct corresponding area of detail, moved to the second position on the prioritized list from twenty-second in the original search.

## **Conclusions**

The LatentSleuth software provided successful results across all quality levels of latent prints for 571 of the 600 prints (95.2%) searched within this validation study. Five hundred and thirty-three of the 600 (88.8%) prints were in the number one position. Not surprisingly, the LatentSleuth software was less effective with low quality latent prints in high comparison complexity instances.

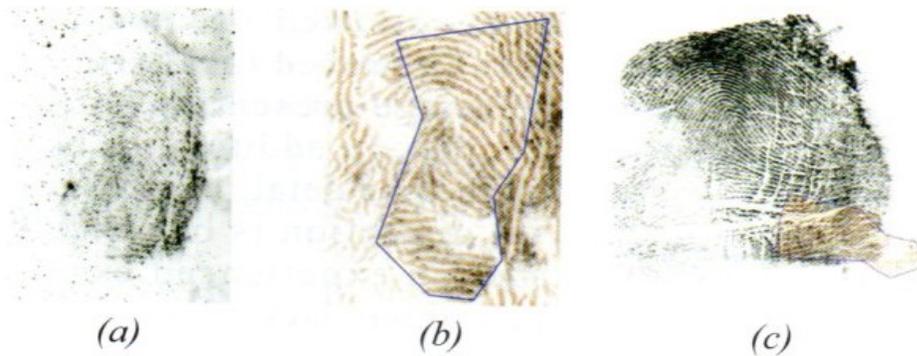


Figure 12

*Low quality print producing lower results after manual processing: (a) latent print with quality region; (b) automated processing; (c) manual processing.*

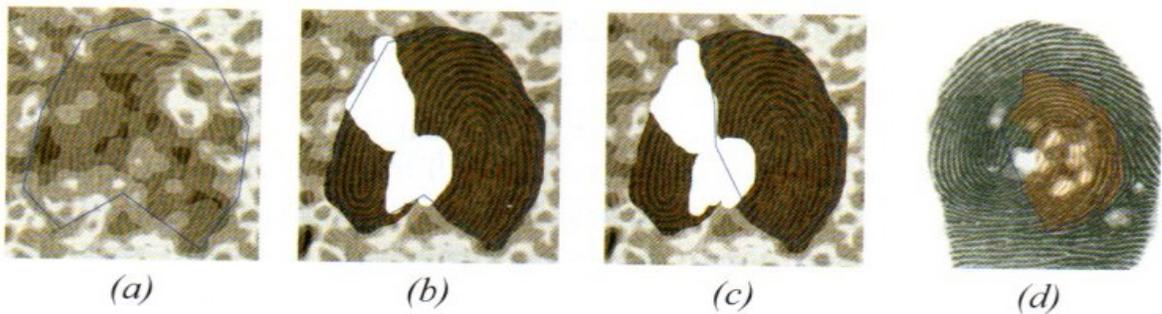


Figure 13

*Low quality latent print produced worse results with manual processing: (a) automated processed latent print with quality region; (b) manual processed latent print with quality region; (c) re-run manual processed latent print with new quality region; (d) true-mate reference with correct overlay.*

### *Lessons Learned*

Only latent fingerprints were used and reported in this study. Accurate results could not be obtained in initial searches with latent palmprints and joints. According to Sciometrics, although LatentSleuth can be used with palmprints, it is not tuned for palmprints at this time, and thus can lead to less reliable results [6]. Thus, all searches involving latent palmprints and lower joints were discontinued.

Selection of the quality region and accurate manual processing (ridge tracing) can have a drastic effect on the location of the true-mate reference image on the prioritized list, especially on the lowest quality latent prints. This demonstrated the need for latent print experience in achieving the best results with LatentSleuth. A lab technician without prior latent print training, hired specifically for this research, conducted the automated searches. Minor adjustments by an experienced examiner to the ridge tracing and to the quality map were made in cases with

nonaccurate or nonhit results followed by new searches. In some instances, these changes improved results from a nonhit to the true-mated reference image presenting in the number one position on the prioritized list. In addition, as noted above, too much editing in areas of unclear detail can have a negative effect; thus, experience with distortion is beneficial. Results achieved after adjustments by an experienced examiner were recorded for this research to eliminate lack of latent print experience as a variable.

As seen with the medium low quality latent prints, subtle differences in ridge tracing and less specific areas of ridge detail have greater impact on larger comparisons. With the addition of more reference images searched, similar ridge flow and groups of features become more common and can negatively affect results.

Areas with creases are masked during the software's automated creation of the quality map. Therefore, some quality ridge detail and valuable information may be excluded from the search. This limitation can be overcome with manual processing of the latent print, but the results will still be impacted due to the automated masking of the reference print image creases.

Certain aspects of the validation study did not represent actual casework. First, the latent prints and corresponding true-mate reference images were purchased from MideoSystems. Although this served to save time, the images were limited to latent prints processed with black or white powders and placed on lift cards of contrasting colors. No latent prints captured after different processing methods that might produce varying colors or contrasts (e.g., ninhydrin, dye stain, etc.) were used. Although this may not have affected accuracy, it would have been ideal to include a variety of processing methods in the validation.

Furthermore, unlike in standard casework, no enhancements of images were conducted prior to entry into the software. Even latent print images of low contrast or those that possessed background interference were entered into the software in their original condition. Potentially, had image enhancements been conducted on the latent prints as would occur in casework, the accuracy of the results may have improved.

Finally, the use of the modified SWGFAST quality table only focused on the clarity of the latent print and the amount of Level 2 and Level 3 details present. Elements such as unknown orientation of the latent prints or specificity of the features

present were not considered in the determination of quality or assessment of difficulty. It is the opinion of the authors that these should be factors in determining quality.

In conclusion, the LatentSleuth software was found to be accurate and was validated for use in casework. The second phase of the study is to implement the LatentSleuth software into casework to evaluate its efficiency and accuracy against traditional manual comparisons.

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