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Fast Fingerprints

Technology for Tracking the Human Barcode

NVIDIA

NVIDIA GTC 2019

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Part 1: Discussion of the Application

The Challenge

- Fingerprints function as the “human barcode” by providing a machine readable means to establish identity. Latent fingerprints are the oils and amino acids fingers deposit on surfaces—they provide a trail of human activity.
- Current latent fingerprint analysis is based on criminal investigation methods and is labor intensive requiring a “person-in-the-loop” which undermines high volume matching.
- Emerging technologies such as mobility create the need for high speed automated methods for processing fingerprints.by treating them as barcodes.

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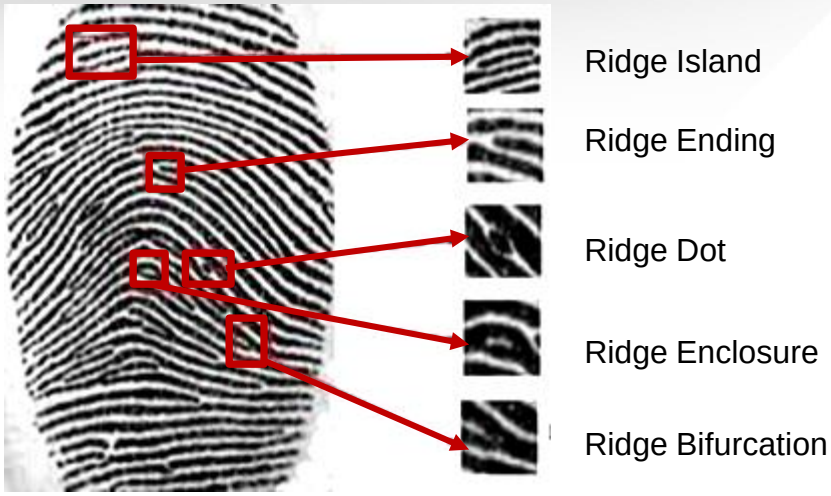
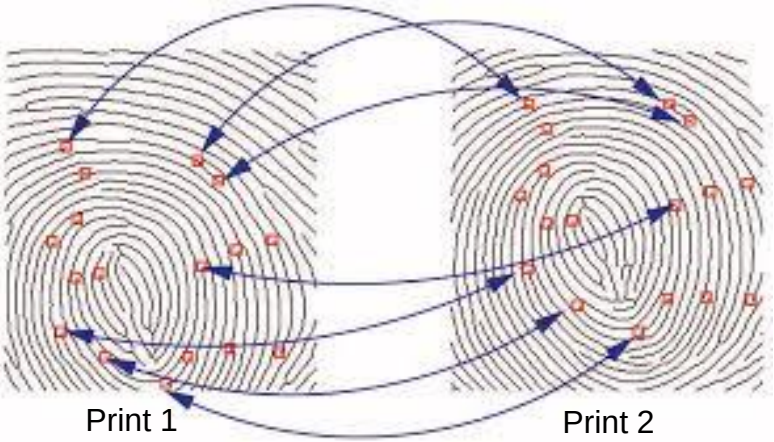
Fingerprint Primer

- "Traditional" fingerprint matching is performed by comparing the patterns of "minutiae" between two prints.
- Minutiae represent points within the print where the friction ridges show a specific characteristic such as a split (bifurcation) or an ending (termination).
- In addition to the specific minutiae points, the directions of the ridges emanating from these points is considered when matching prints.
- For forensic purposes several minutiae point matches are required.
- Prints without sufficient minutiae are labeled to be of "no information value" (NIV).



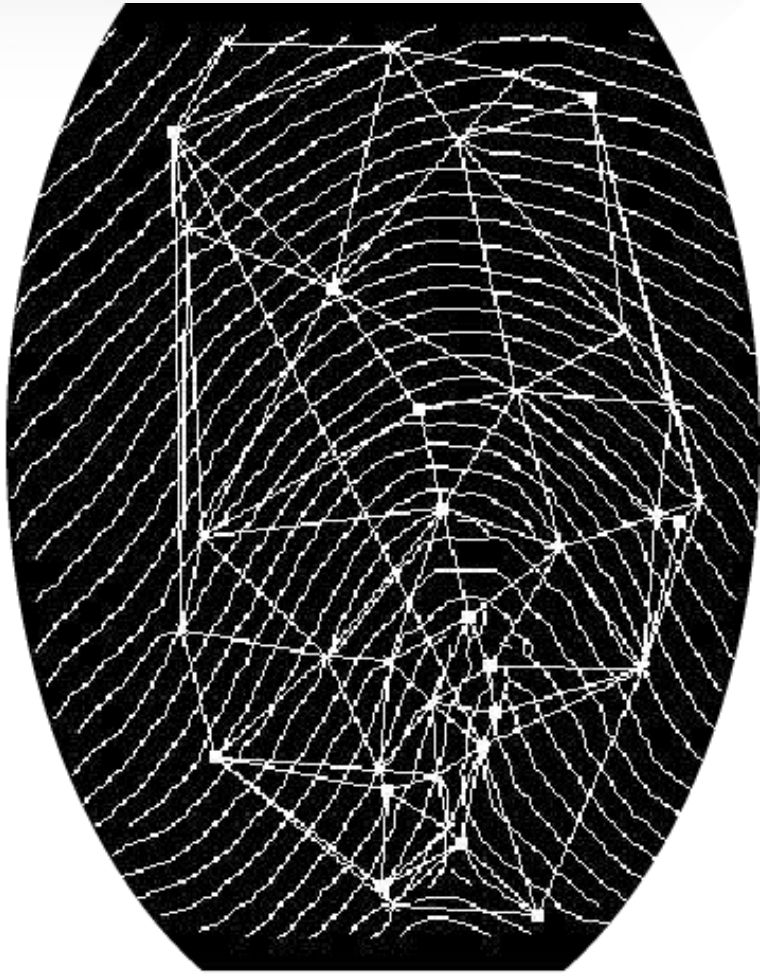
Examples of Minutiae



Matching by Minutiae

Automated Fingerprint Identification

- Fingerprint matching is performed by Automated Fingerprint Identification Systems (AFIS)..
- AFIS technology encodes the data from the minutiae points into “templates” which can be matched against other templates in large databases.
- Examples of large authoritative databases include the FBI’s NGI system, the DoD’s ABIS system and the DHS IDENT system each containing millions of reference fingerprints.
- For matching purposes, there are two types of fingerprints: (1) Livescan and (2) Latents. Automated matching of Livescan prints is a solved problem.



Minutiae encoding with triangulation.

Latent Fingerprints

- Traditional minutia-based fingerprint matching becomes confounded with latent fingerprints.
- Latent fingerprints are deposits of oils and amino acids that a finger leaves upon touching a surface.
- Latents suffer from smearing, distortion and missing information.
- Many latents lack the minutiae that are the foundation of automated matching.

Examples of latent fingerprint developed using powder at crime scene.

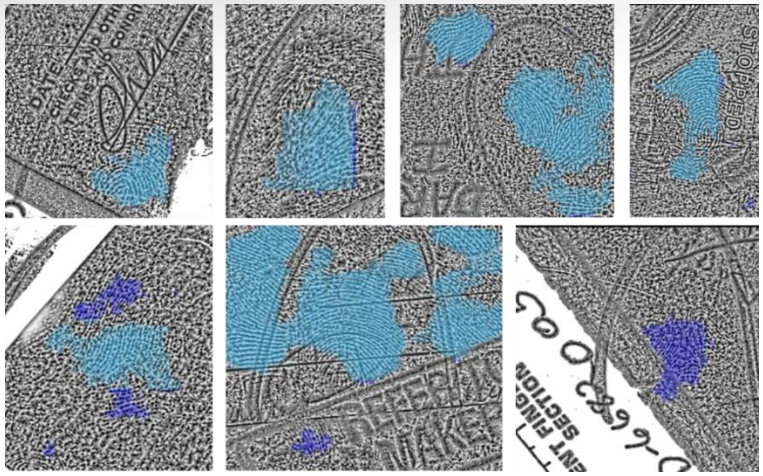
Why Latents are Important

- Latent fingerprints are similar to DNA in that they remain after a person has left the scene.
- Although not as precise as DNA (parts per billion), latents have a strong statistical foundation for supporting identity (parts per million).
- Latents offer an unobtrusive and low cost way to verify identity.
- There are two venues where latents are emerging as critical sources of identity: (1) screening and (2) mobility.

Fingerprints can be obtained from paper documents enabling identification of persons possible from discarded paper..

Screening and Forensic Intelligence

- Background checking is currently performed against the FBI's NGI database which contains images of fingerprints captured at the time of arrest.
- Additionally, numerous latent prints are collected from crime scenes, sensitive sites, weapons, explosive devices and the like. **Unlike the FBI collection, these represent the ones who got away!**
- Deep learning methods exist to load these latents into databases to support screening.
- Once loaded into a database, these collected latents offer a totally new source of screening information.
- Additionally, an expanded source of latents supports exploiting the intelligence value of fingerprints.



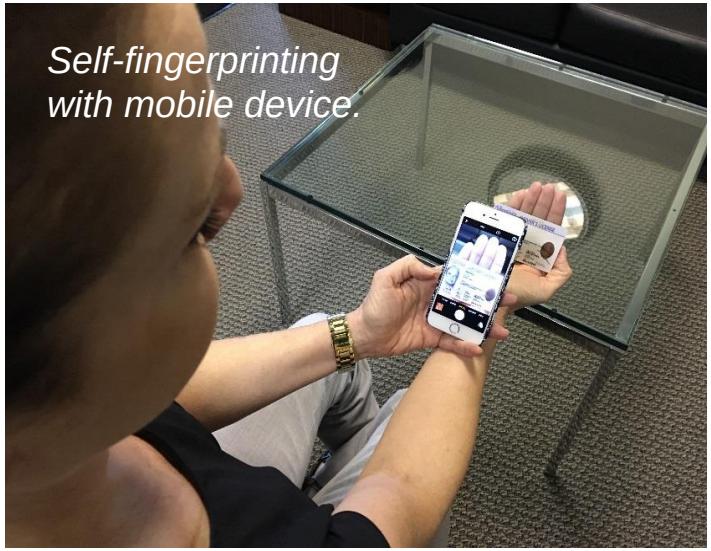
Latents obtained from "sensitive site".

Collected latents used for real-time screening.

Mobile Contactless Fingerprints

- Smartphones are ubiquitous devices with very powerful sensors.
- A 12 megapixel camera can capture very detailed images of fingerprints from hands.
- However, unlike a dedicated scanner, there are several variables that effect the quality of images captured from phones: movement, subject distance, pitch and yaw of the phone or the hand, lighting, occlusion.
- Finger Images from mobile devices have characteristics that make them very similar to latent fingerprints for matching purpose.

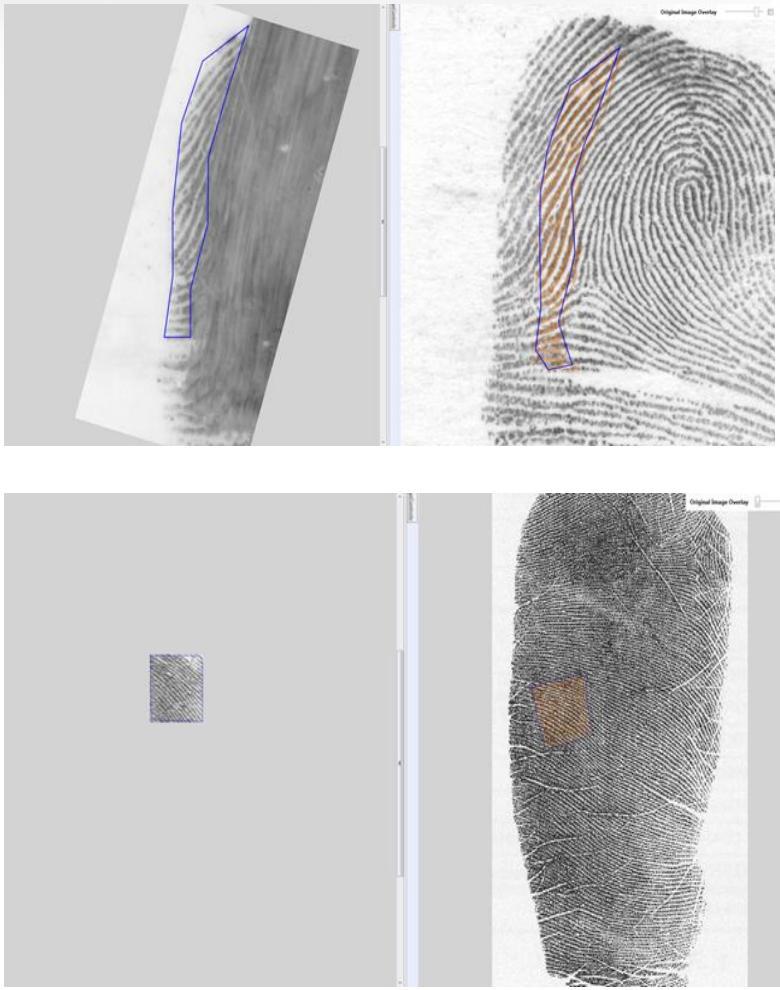

Using mobile phone as a fingerprint collector..


Self-fingerprinting with mobile device.

Latent Sleuth

- LatentSleuth originated under Project GRAFF was an FBI-funded effort to develop a fingerprint matcher expressly designed for latent fingerprints.
- .LatentSleuth is an AFIS designed expressly to work with small, poor quality latent prints.
- LatentSleuth employs a Ridge-centric matching method which engages the relationship among ridges to exploit all the information in a latent print.
- LatentSleuth can match fingerprints that confound “traditional” minutiae-based matchers.
- LatentSleuth can operate “with no human in the loop”.
- LatentSleuth is currently implemented at the FBI and several other locations.

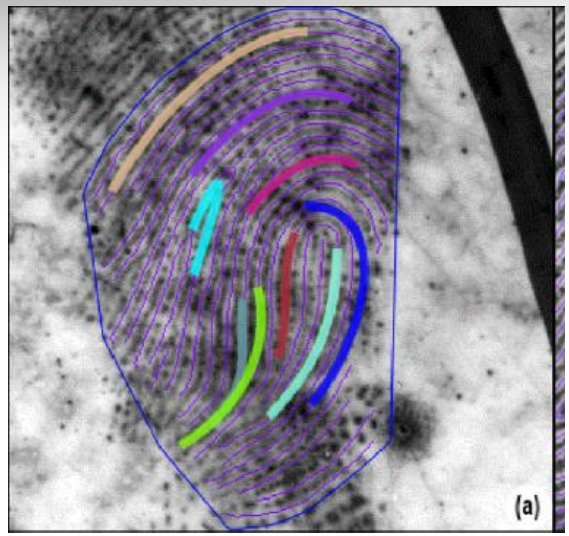
Latent Print **Latent matched to Reference**



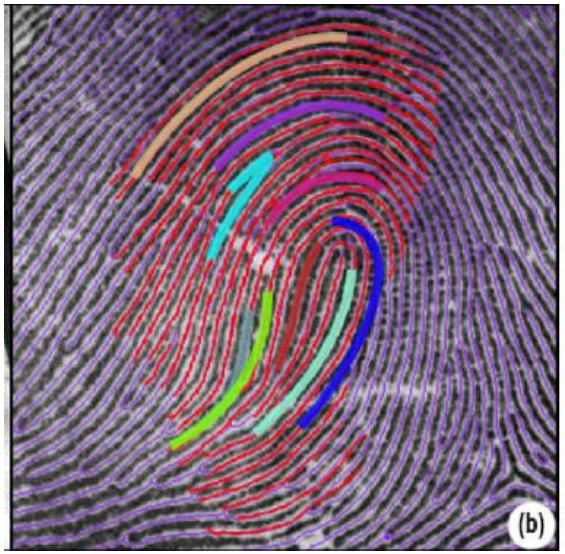
Examples extremely difficult latent prints automatically matched by LatentSleuth.

Ridge-specific Markers

- LatentSleuth employs a technique called “Ridge-specific Markers (RSMs).
- RSMs are sections of fingerprint ridges articulated through Bezier curves.
- By finding corresponding pairings of these curves between a latent and reference print, LatentSleuth can match prints without minutiae.
- This method is enables very precise pattern matching to be performed by calculating a non-linear warp between latent and reference spaces overcoming distortion due to the elasticity of skin.



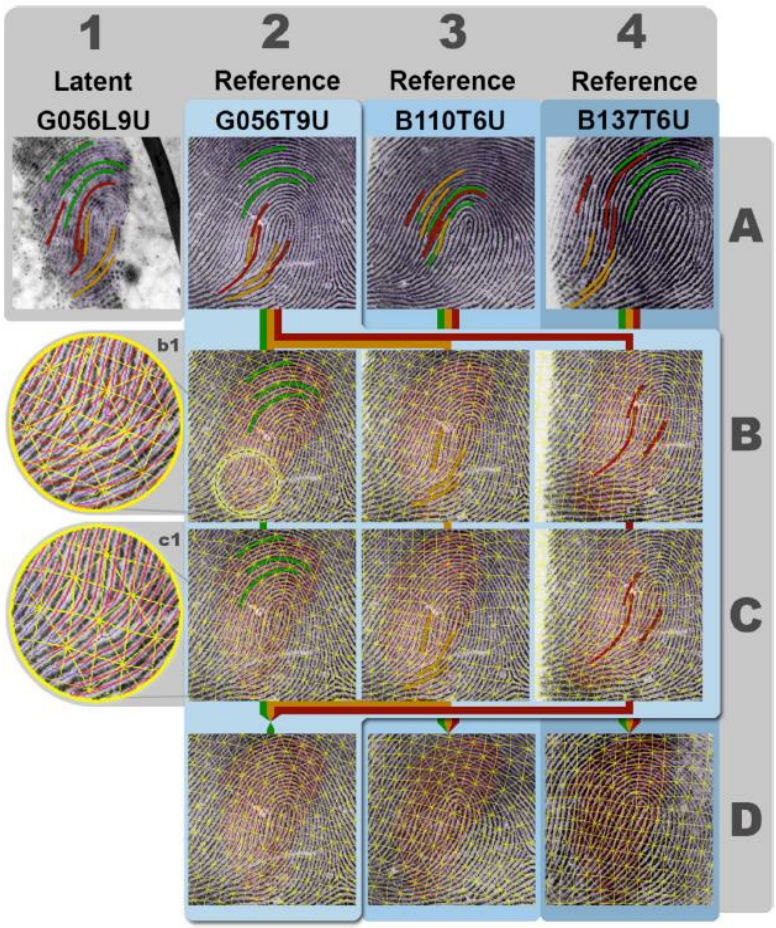
Ridges detected in latent image..



Ridges mapped in reference image.

RSMs: Step-by-step

- Column 1 shows the latent print.
- Column 2 shows the correct mated reference print.
- Columns 3 and 4 show two incorrect latent prints.
- The red, green and yellow segments show Bezier curves matched between the latent and various reference prints.
- Row A shows the first attempt at seed matching.
- Row B shows the initial warp given the initial seed matching between the latent and references.
- Row C shows a refined warp given additional seed matching.
- Row D shows the final overlays between the latent and references.

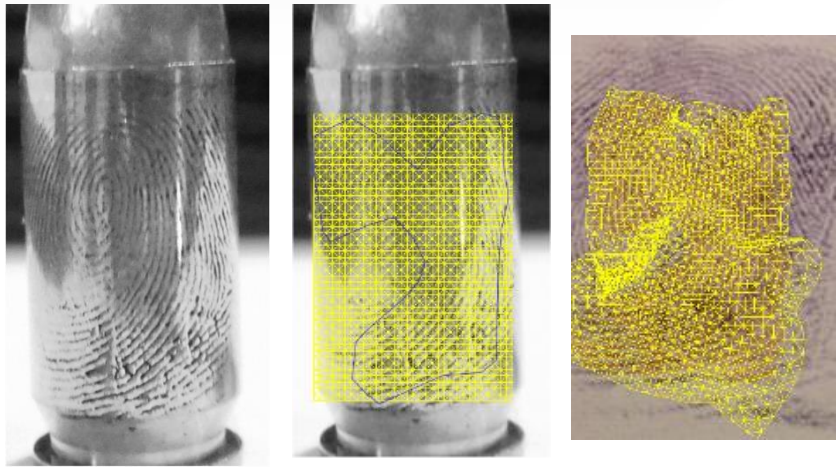


Example of latent fitting to correct mate and two incorrect references.

The Warp

- The Ridge-specific marker method generates an accurate mapping of the latent onto the reference image.
- This mapping accounts for surface geometry as well as stretching of both latent and reference prints due to the elasticity of skin.
- The result is a precise overlaying of the latent on the reference with alignment of all significant features.
- This alignment enables creation of an objective score that makes a statistical statement about the goodness of fit between the latent and reference.

Latent Print **Latent Warp** **Reference Warp**



Overlay of latent from 3-dimensional shell casing successfully placed on correct reference print.

The Power of the Warp

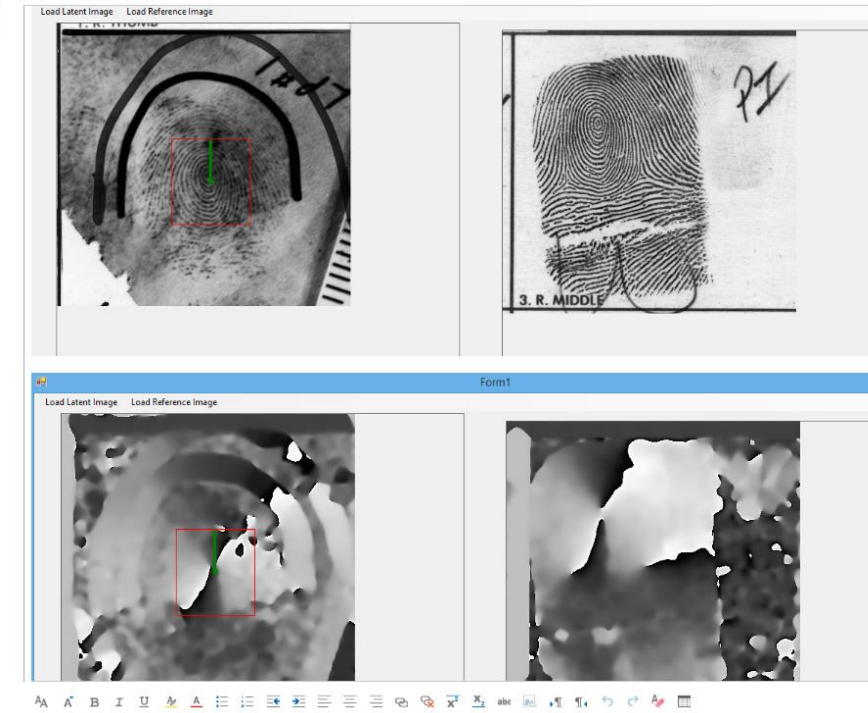
- The warp not only accounts for the elasticity of skin but it also overcomes scaling issues resulting from growth.
- The upper image on the right shows a kindergarten “refrigerator magnet” project created several years ago. The magnet remained on a succession of refrigerators over the last 30 years.
- The lower image show the child’s fingerprint successfully fitted into the adult finger of the same individual overcoming scaling issues related to human growth.

Child’s refrigerator magnet art project..

Fingerprint matched to adult finger.

Speeding up the Process by Indexing

- The RSM process is highly accurate but computationally intensive.
- One method for acceleration entails using either minutiae or directional fields to index reference images enabling the generation of a subset of references that may match a particular latent while eliminating references that cannot possibly match.
- The image on the right shows the ridge directions encoded in different shades of gray revealing a pattern that can be matched.



Directional field encoding method.

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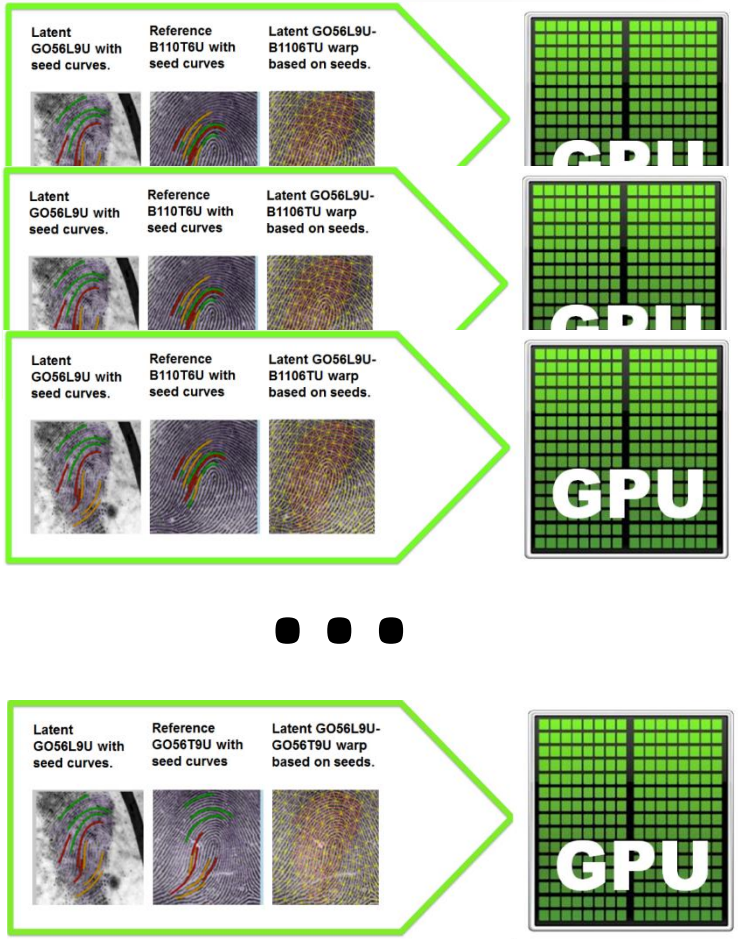
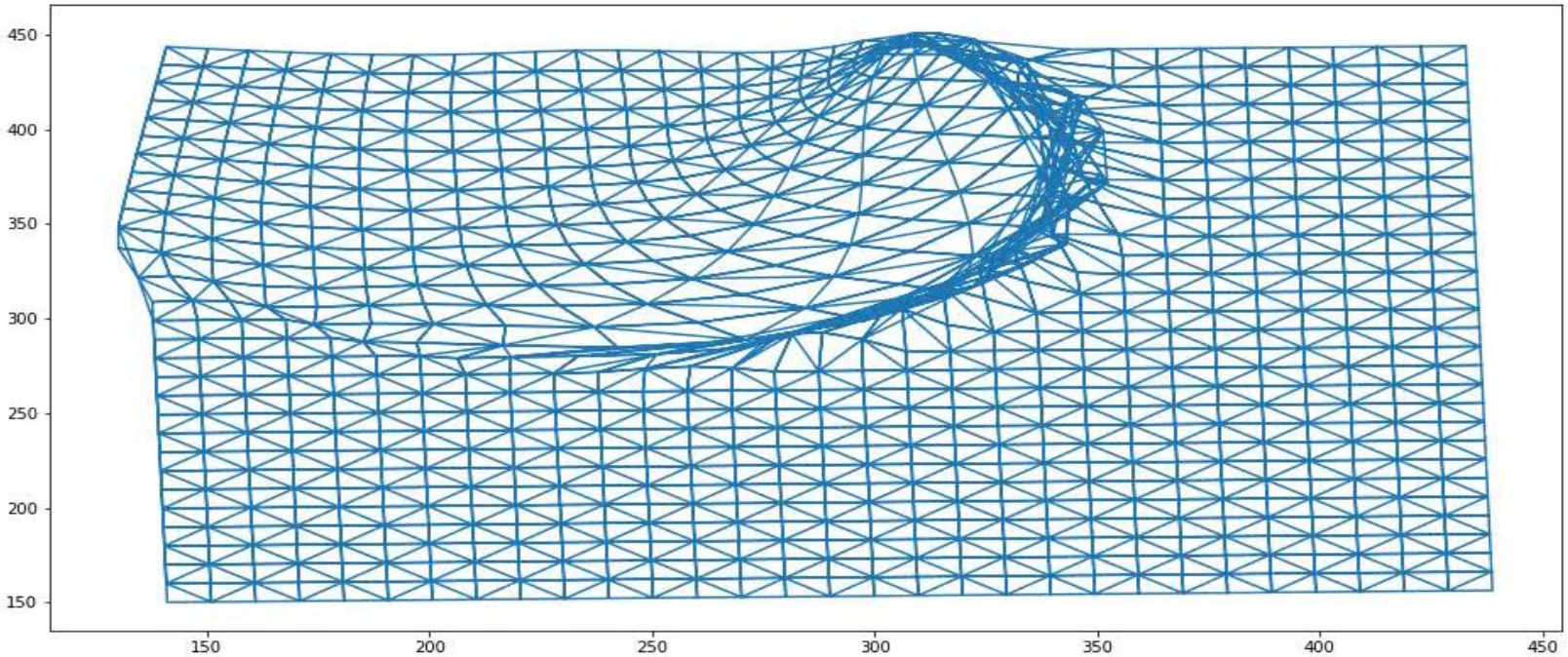
Part 2: Accelerating throughput by GPUs

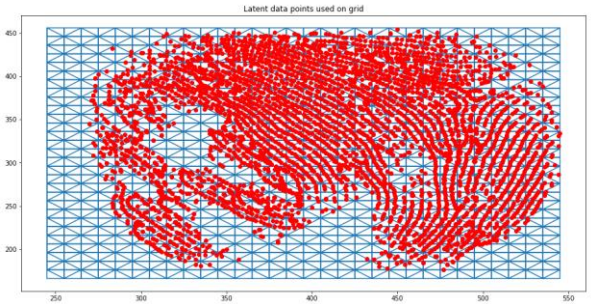
Speeding up the Process GPUs

- The repetitive nature of the RSM process is well suited for acceleration by GPUs.
- At the heart of the method is the generation of “seeds” between the latent print and various reference prints.
- These seed ultimately lead to the production of the warp and goodness of fit score that determines the correct match.
- The warp generation process is repetitive and iterative. That is, while seed production can be parallelized, there are also contingent relationships among the seeds.

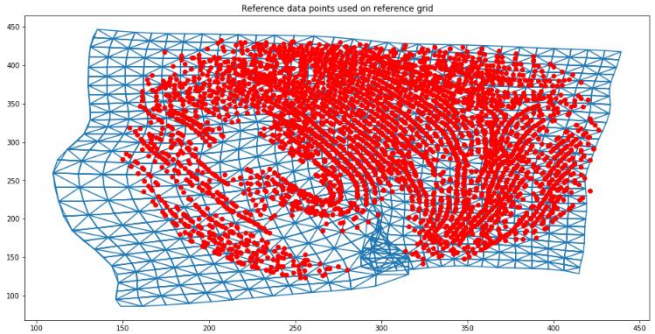


The Evolution of the Warp





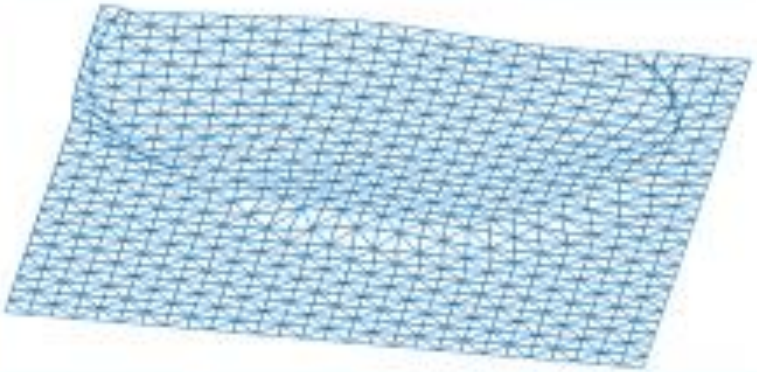
Latent Warp



Fitted Reference Warp

Fingerprint Speedup Results

- Results comparison CPU vs GPU
  - Exponential speedup with GPU algorithm
  - 755 LATENT/150,198 REFERENCE lines
  - CPU: 36000 computations per second
  - GPU Solution: 3 billion per second
  - 83000% Improvement



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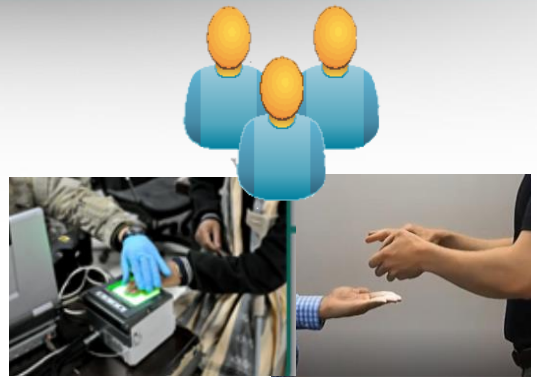
Part 3: Immediate Applications of Automated Latent Print Matching

CONOP 1: Screening by Latents

LatentSleuth supported by GPU technology supports real time screening of individuals against authoritative databases such as collections of unresolved latent fingerprints. In this CONOP, soldier scans hands of persons of interest (either with smartphone or contact scanner). Captured prints are matched against local Biometrically Enhanced Watch List (BEWL) or sent to DoD ABIS. Since process is "lights out", results available quickly.

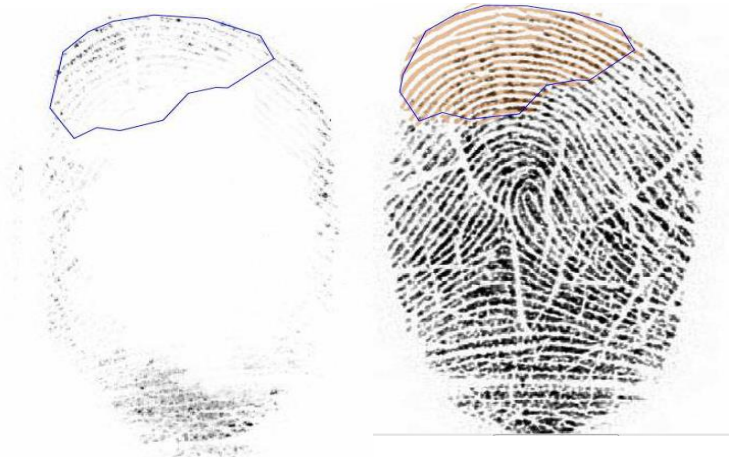


1. *Fingerprints captured in real time from persons of interest using either mobile phone or contact scanner.*
2. *Captured prints matched either by LatentSleuth locally or by LatentSleuth in conjunction with a large database.*
3. *Newly collected prints are matched against latents previously collected.*

CONOP 2: Seeing through the Disguise

LatentSleuth supported by GPU technology supports real time matching of surgically altered or obliterated fingerprints against reference prints. Since the technology can work with very small patches of ridge structure, LatentSleuth can detect regions of the print that have been surgically relocated as well as the peripheral regions of prints that have been destroyed through burning or chemicals.

Surgically altered fingerprints.

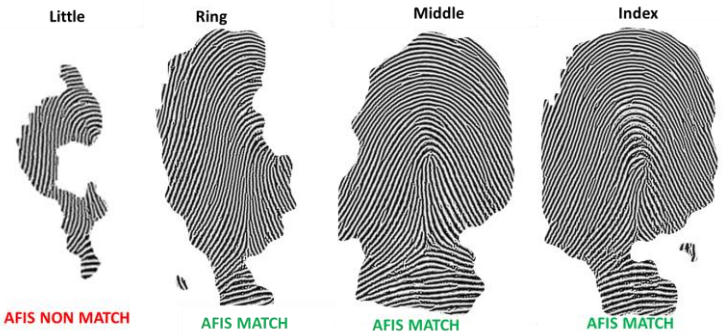


Chemically obliterated fingerprints.

CONOP 3: Contactless Fingerprinting

Automated Latent fingerprint matching supported by GPU technology will boost performance of contactless fingerprinting—prints captured by camera on mobile device—by enabling identification of all fingers. As shown by the figure on the right, some fingers may image poorly and LatentSleuth can recover even the most poorly imaged print.

Person	Set	Commercial AFIS	AFIS Non-matches recovered by LatentSleuth	Total Matched (Rank 1)
Person 1	1	6	2	8
	2	8	2	10
	3	9	1	10
Person 2	1	4	4	8
	2	6	3	9
	3	4	4	8
Person 3	1	4	4	8
	2	6	2	8
	3	5	2	7
Person 4	1	4	4	8
	2	3	3	6
	3	4	3	7
Person 5	1	7	3	10
	2	6	3	9
	3	6	2	8



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Part 4: Questions, Answers and Contacts

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