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Lights-out Latent Processing (Automatic Latent Proc.) Today and Tomorrow

NIST Latent Testing Workshop
March 19 and 20, 2009

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Preliminary Questions at 2006 WS

- **Is automatic latent encoding feasible?**
  - → **Yes (Topic 1a)**
- **Is automatic latent verification feasible?**
  - → **Very limited (Topic 1b)**
- **How much accuracy degradation is acceptable?**
  - → **Trade-off on cost (Topic 1c)**
- **How much cost increase is acceptable?**
  - → **Guideline shown in ELFT07 test plan (Topic 1c)**

Topic 1a

Image-only Latent Matching

(Automatic Latent Proc.)

1a. Image-only Latent Matching

1a.1 Necessary tech. for auto-latent

1) Latent image proc. and features extraction (FE)

a) Latent background noise removal and contrast enhancement of ridge area

b) Latent ridge recognition and ridge enhancement

c) Latent trimming/crop (ridge area definition)

2) Matching algorithm for auto-latent

- Robust to low reliable features such as false minutiae and unreliable core/delta info

3) Fusion tech. to improve total accuracy

- Using multiple FE & matching algorithms

1a. Image-only Latent Matching

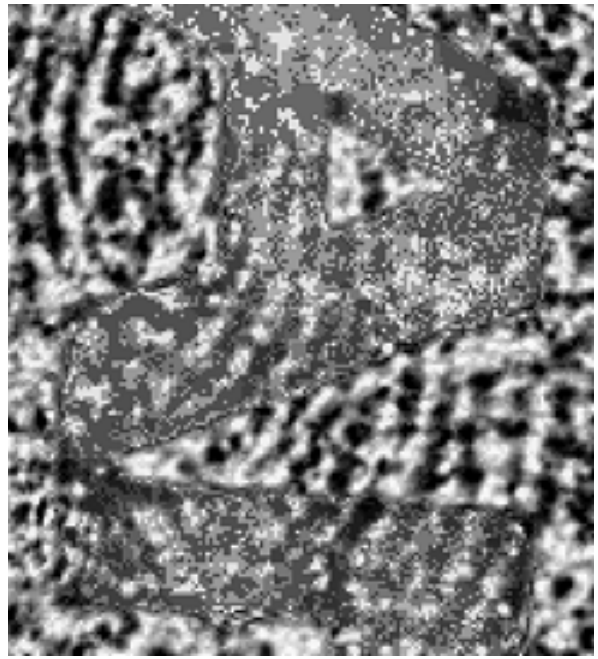
1a.2 Latent image processing

1) NBRE: Noise Boundary Recognized Enhancement

→ **Strong enhancement without "edge effect"**

Original

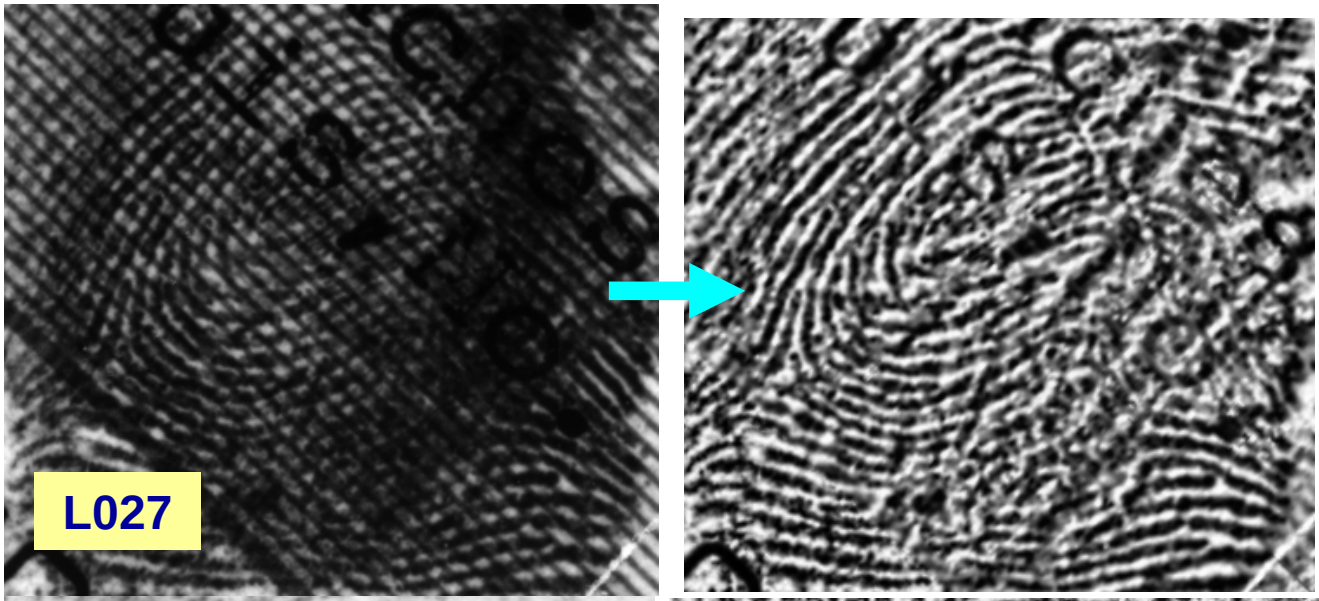
L194



NBRE

1a. Image-only Latent Matching

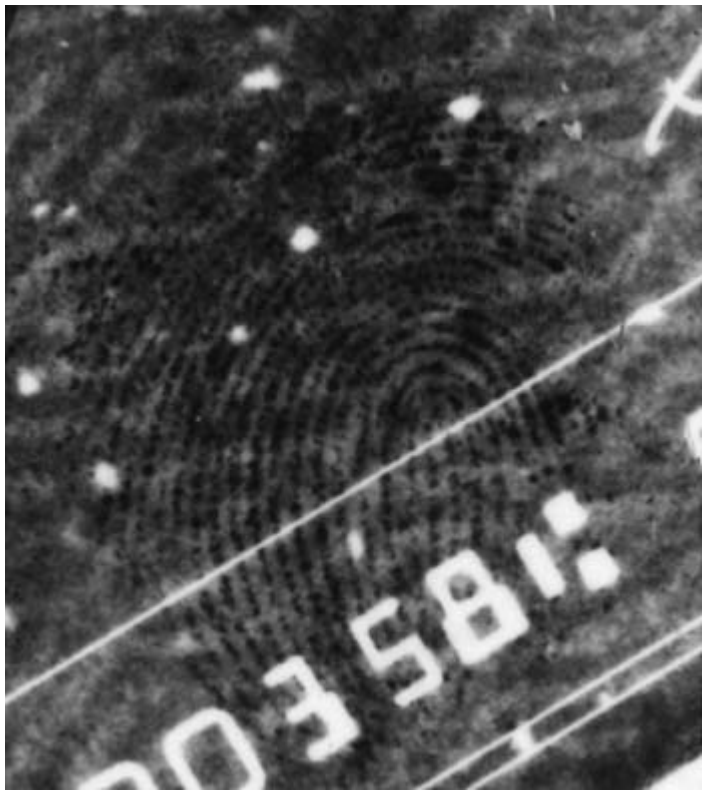
2) Line noise removal with NBRE



3) Char. noise removal with NBRE

1a. Image-only Latent Matching

4) Latent image area full auto trimming (crop)



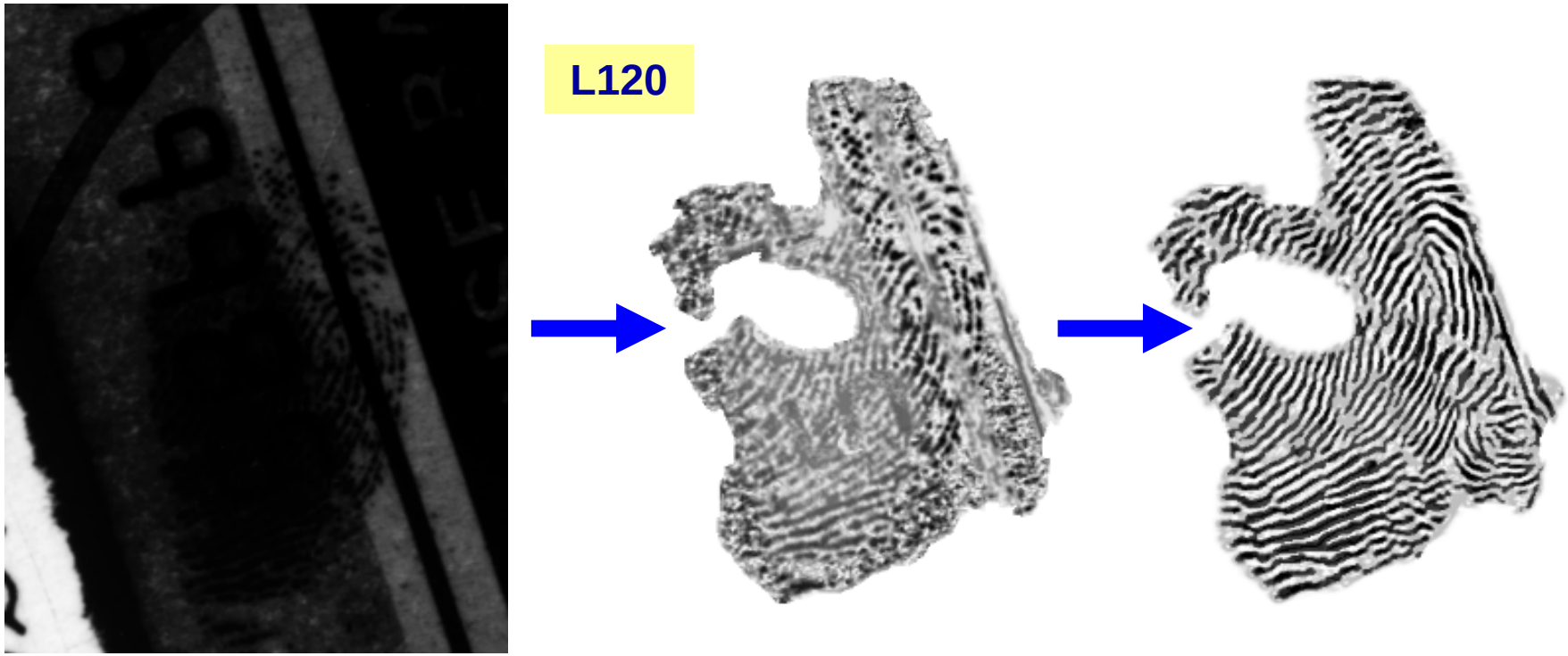
Original

L020

Cropped after noise removal

1a. Image-only Latent Matching

5) Latent image ridge extraction



Original

Trimmed after noise removal

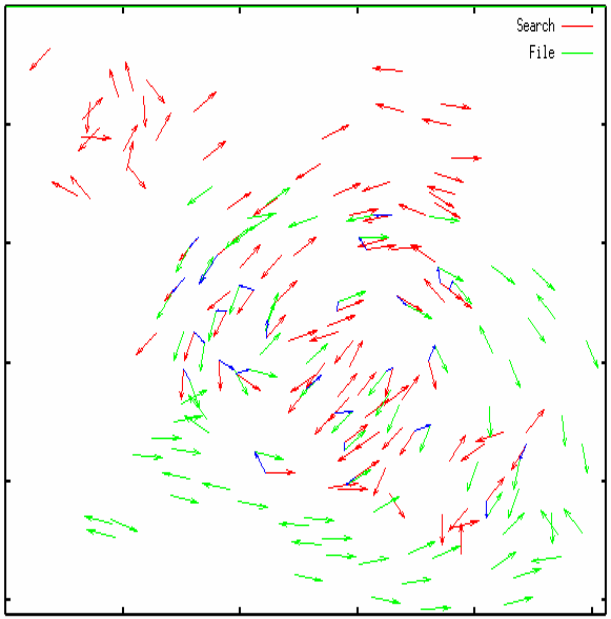
Ridge extracted

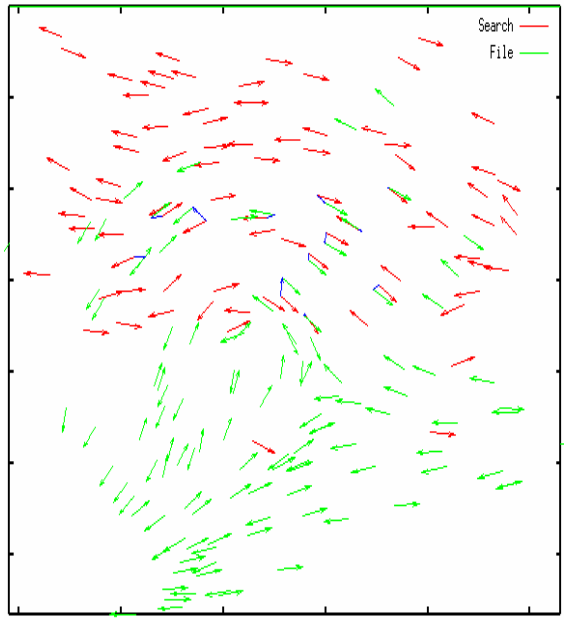
1a. Image-only Latent Matching

1a.3 Matching algorithm for auto-latent

1) Robust matching to unreliable features

2) Smart-matcher for Auto Template Optimized Method (SATO_M) has shown significant improvement





Search Minutia

File Minutia

Improperly trimmed latent (left) and overlapped (right) latent samples.

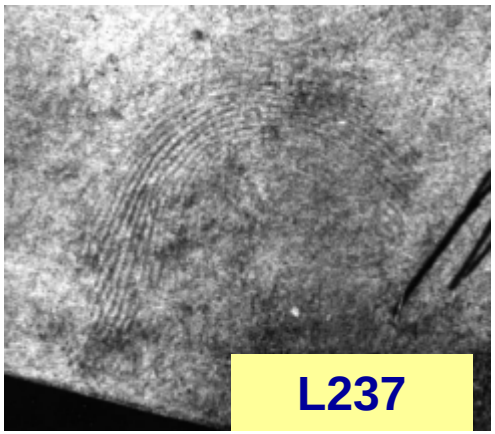
SATO_M increases hit cases even with many false minutiae caused by low quality image and by improper trimming.

1a. Image-only Latent Matching

1a.4 Fusion tech. for auto-latent

1) Fusion matching using various sets of search minutiae

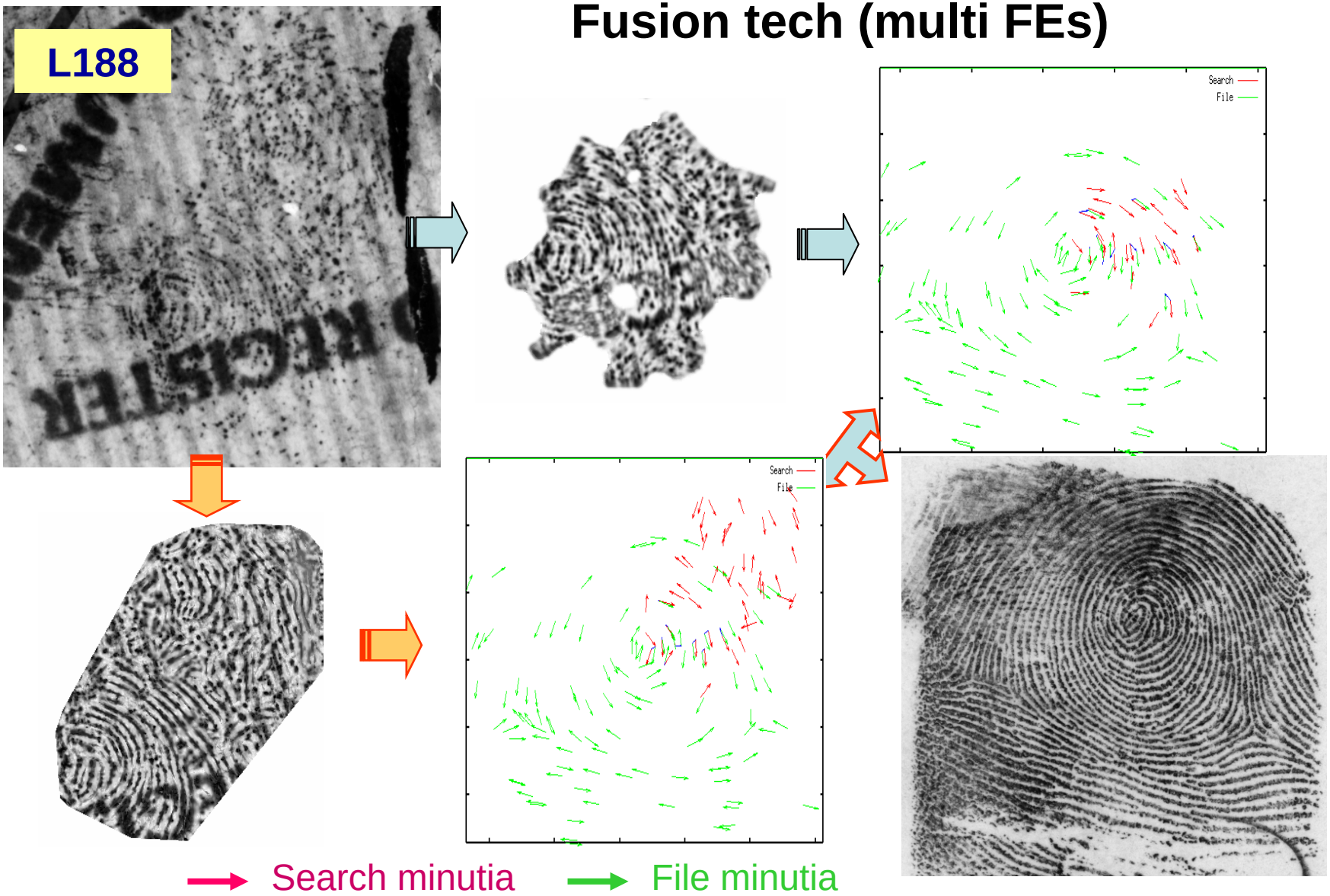
2) Fusion matching using various sets of both search and file minutiae



Different trimming and ridge enhancements

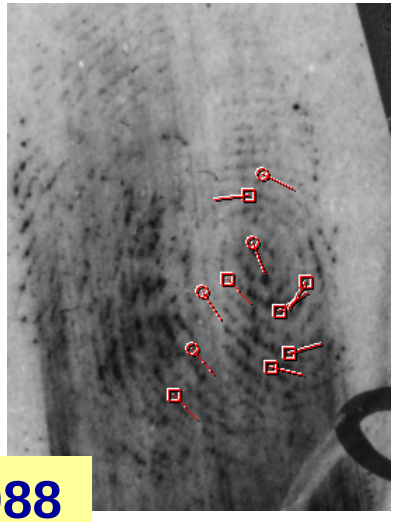
Fusing matching scores from multiple technologies can improve final accuracy. Fusion tech. can increase true hits (by increasing mate scores) as well as can reduce false hits (by decreasing non-mate scores).

1a. Image-only Latent Matching

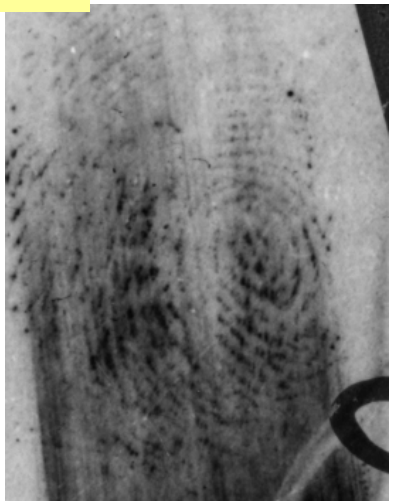


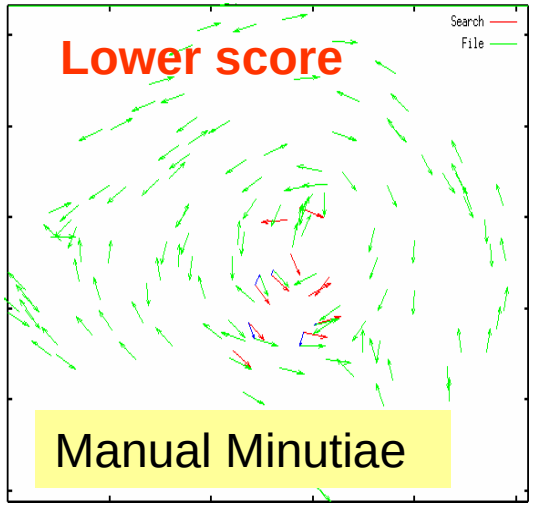
1a. Image-only Latent Matching

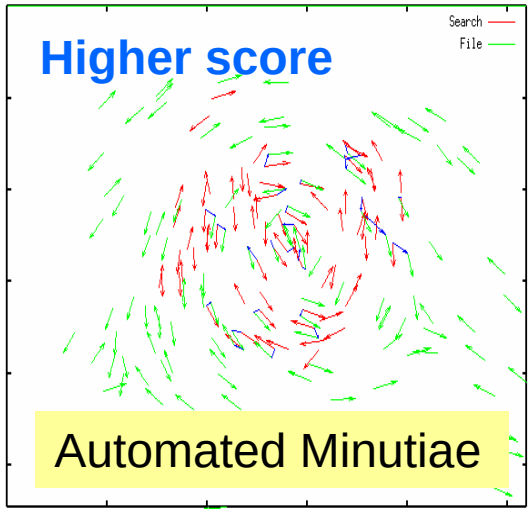
In some cases, auto-latent shows better results.



L088





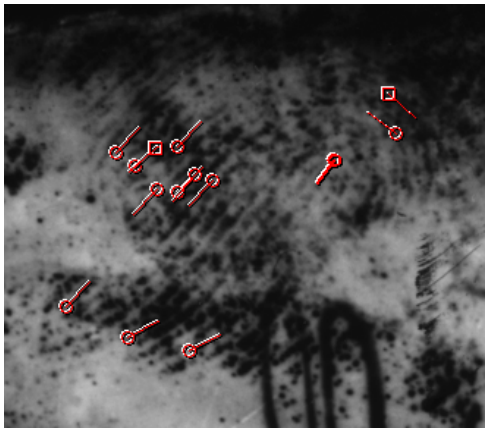


Manual minutiae from NIST SD#27 Ideal

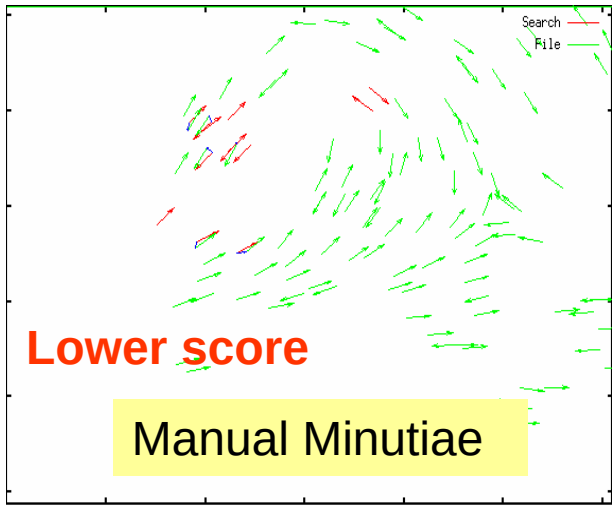
Sample #1

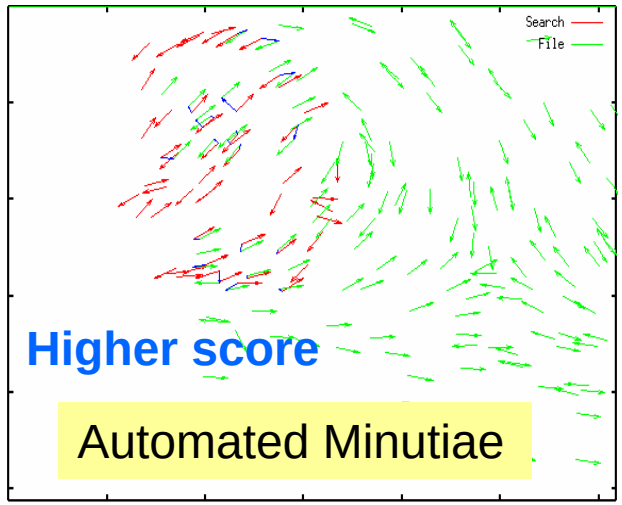
1a. Image-only Latent Matching

In some cases, auto-latent shows better results.



L291





Manual minutiae from NIST SD#27 Ideal

Sample #2

1a. Image-only Latent Matching

1a.5 Ongoing research after ELFT07 Phase II

1) We keep improving auto-latent algorithms.

2) NIST Special Data Base #27 (SD#27) is very helpful to improve algorithms because:

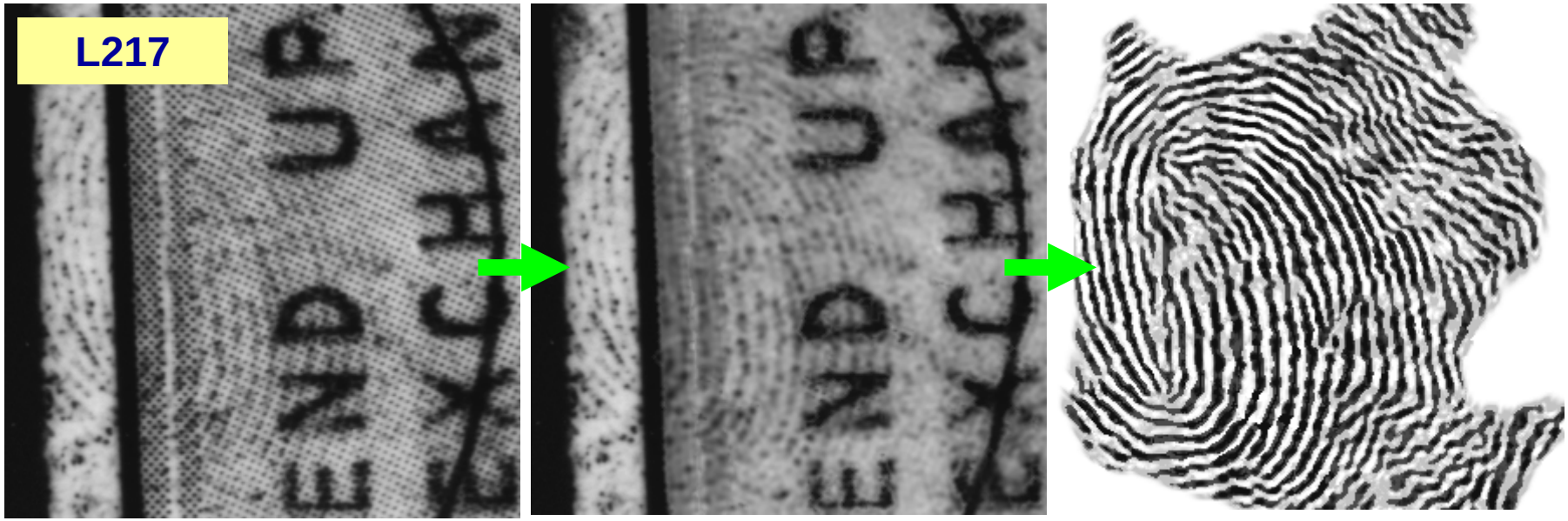
- **a. Manually marked minutiae associated**
- **b. Identifiable by examiners**
- **c. Including many "tough" data**
  - **(*) Not current AFIS hits**
- **d. IQS scanned images**

→ Excellent test DB to improve accuracy

1a. Image-only Latent Matching

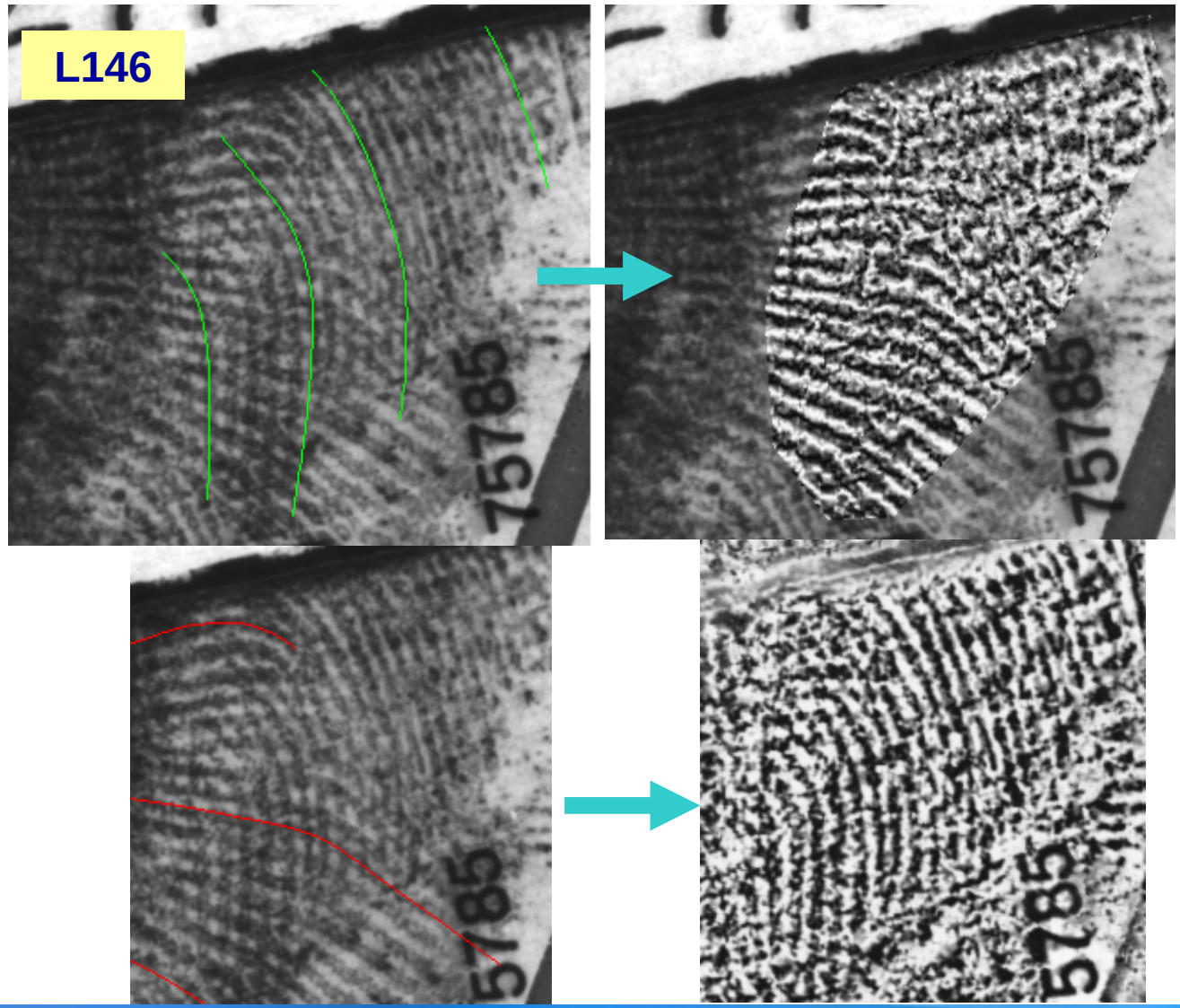
1) Progress on periodic pattern removal

Popular algorithms to remove periodic (frequent) pattern noise have side-effects to degrade “true ridges” and such side-effects are major obstacles when implementing them on auto-latent. We have solved such problem for some cases.



1a. Image-only Latent Matching

2) Progress on overlapped ridge removal



Current method requires manual input for undesired ridge lines (green lines on left top and red lines on left bottom).

We will research a way to automate this process.

1a. Image-only Latent Matching

1a.6 Expansion of test data base

1) Because there is **no good test set except SD#27**, current researches may be over-tuned to SD#27.
2) If SD#27 (from FBI) does not represent distribution of operational latent quality (characteristics), it is not beneficial for law enforcement community.
3) It is suggested to expand latent DB to include variety of "**problematic**" latent prints and also to represent overall distribution of latent quality.

If we researchers/vendors do not know what an underlying problem is in the first place, its solution can never be devised.

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Topic 1b

Automated Match Determinations for Image-only or Feature-based Latent matching

1b. Latent Match Determination

1b.1 Manual determination (visual verification)

1) Time consuming
2) Requires expert skill for difficult cases

(*) Difficult cases require long time even for expert examiners

3) Cost increases as number of candidates increase

1b. Latent Match Determination

1b.2 Fully automatic determination (verification)

Dependent on image quality

- **OK for very good quality latent prints & if its mate in DB**
  - **(*) 1st rank and high score → Confident hit**
- **Very difficult (almost impossible) for many latent prints**
  - **(*) 1st rank but low score → Inconclusive**
  - **2nd rank or low → Almost impossible**

ELFT07 Phase II report says,

"Analyzing NEC M1,moving from the first operational point to the second cuts the examiner workload by up to half (FPIR from 95% to 47%), while missed identifications are increased by 1% (FNIR 3% to 4%). It is a policy issue to determine if this is an acceptable trade-off."

1b. Latent Match Determination

ELFT07 Phase II report says,

"Automatic determinations of high-likelihood hits can be used operationally to flag likely matches in low-priority cases that might otherwise never warrant examiner time, or to prioritize an examiner's workload based on the likelihood of match. In either case, automatic determinations of high-likelihood hits could be used for areas with an excessive backlog to maximize examiner efficiency".

At FNIR of 8% the FPIR is 1% on NEC M1.
At this operating point, identifications are successfully made 92% of the time with only 1% of the examiner's comparisons including non-mates".

1b. Latent Match Determination

1b.3 Manual and automatic determination

1) Full automatic determination

1st Rank and high score → Auto-hit

(*) Final identification by expert examiners suggested

Note: Use of the latest algorithms is expected to make auto-hit determination for 20-30% searches assuming NIST DB #27 level quality.

2) Manual determination

Inconclusive cases (non auto-hit) → Manual proc.

1b. Latent Match Determination

1b.4 Manual determination improvement

1) Screening (preliminary visual verification)

a) Screening by novice examiners (w/o long training) is very effective way to reduce inconclusive cases

b) Suggested to check rank 1 candidate (or up to 3) to reduce workload

2) Determination

a) Final determination (Identification) by expert examiners is only limited to “probable cases”.

b) Zero (most of cases) or one candidate per search

Topic 1c

Using Increased Automation and Business Practices to make more effective use of Latent Examiners

1c. Effective Use of Examiners

1c.1 Computer cost and examiner cost

1) Auto-latent cost

15 seconds/finger; (*) Insufficient for very poor rolled print

Phases I and & II Execution Time Limits	
Primary SDK	
Background Enrollment	Total Time (seconds) ≤150 * (number of ten-prints in background)
Latent Enroll	350 seconds per image for Phase I; 600 seconds per image for Phase II
Search	Time per Search (seconds) ≤ 0.2* (number of ten-p rints in background) … Phase I ≤ 0. 25* (number of ten-prints in background) … Phase II

~ 6 minutes/latent

40 or 50 matches per sec.

ELFT07 supposes that much more computation power is needed to do auto-latent.

This is not a problem because the ratio of computer/examiner cost becomes smaller every year.

1c. Effective Use of Examiners

2) System cost study with auto-latent

Search time (CPU cost) is the most critical when auto-latent is implemented. Background enrollment time is next critical. Latent enroll time is negligible.

Case Study: 1M DB, 3K cards/day, 200 latent prints/day

Background enrollment:	approx. 80 sec/card (NEC M1)
Latent enroll:	approx. 60 sec/latent (NEC M1)
Search:	0.2 sec/card (NEC M1)

1) Background DB conversion: 926 CPU * day (1M x 80sec)

→ "One-time" proc. Be completed in one months with 31 CPUs

2) Daily background enrollment: 3 CPUs (3K x 80sec)

3) Daily latent enrollment: 0.2 CPU (200 x 60sec)

4) Daily latent search: 463 CPUs (200 x 1M x 0.2sec)

Latent search cost exceeds 99% of the total cost.

1c. Effective Use of Examiners

3) Comparison of computer and examiner costs

Case Study: 1M DB, 3K cards/day, 200 latent prints/day
→ 500 CPUs sufficient to do auto-latent

a) Cost for auto-latent capability → $1M (?) range (CPUs, memory, etc.)

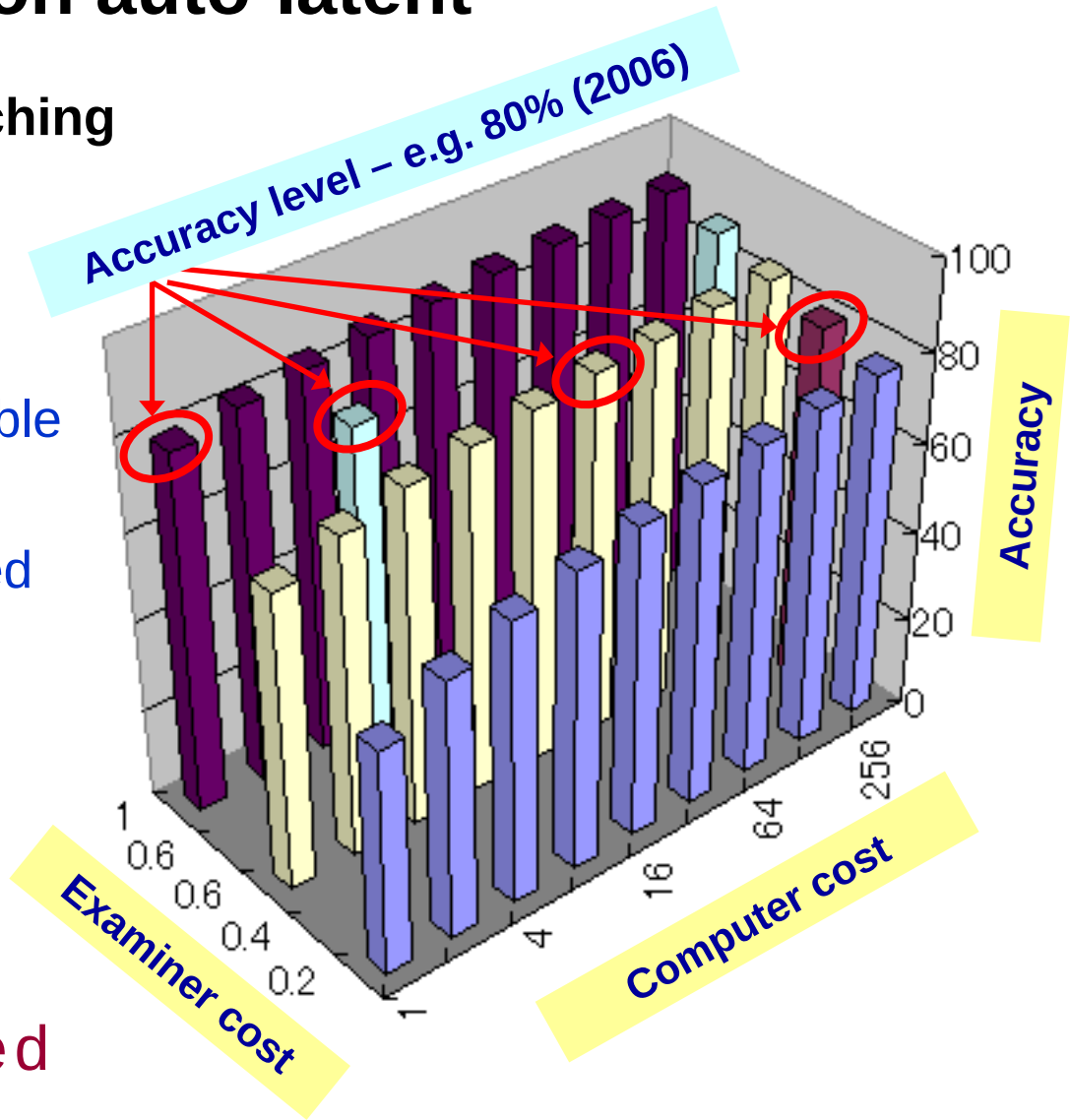
b) Cost for an examiner for 5 years → $1M range

Worth to consider implementation of auto-latent capability from cost-effectiveness!

1c. Effective Use of Examiners

1c.2 Cost trade-off on auto-latent

- **Latent encoding and matching**
  → Auto-latent feasible
- **Screening (candidate reduction)**
  → Auto-latent partially feasible
- **Identification**
  → Expert examiners required



More robust, smart and complicated algorithms needed

→ Computer cost increase be accepted

1c. Effective Use of Examiners

1c.3 Use of novice examiners

1) **Use novices on easier tasks such as:**
   - a) ROI setting
   - b) Orientation setting
   - c) “Center point of Reference” setting
   - d) Screening of candidates
     - (*) First (pre) match-determination

2) **Expert examiners are dedicated only to tougher cases and more important tasks.**

3) **With support of novices, workload of expert examiners can be reduced without “significant” accuracy degradation.**

1c. Effective Use of Examiners

1c.4 Maximum use of auto-latent

1) Auto-latent can free up expert examiners work on some (easy) cases. Then, experts can devote themselves on tougher and more important cases.

2) Future AFIS shall be an integration of auto-latent and manual proc.

Case 1: Auto-latent is conducted first and then manual proc. is conducted when auto-latent was unsuccessful.

Case 2: Auto-latent and manual proc. are simultaneously conducted. If auto-latent returns confident-hit, manual proc. can be seized. If not, scores from both processes are fused to produce single candidate list.

Conclusion for Auto-Latent

1) Auto-latent has been proved feasible.

2) Expert examiners' aid is still needed to "properly" process latent prints.

3) Ideal and future AFIS shall be an integration of auto-latent and manual proc.

4) Auto-latent will free up expert examiners work on easy cases so that he/she can devote on tougher and more important cases.

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