



# Latent (Partial Print) Processing and Matching: Thresholds and Parameters for Automatic Decisions

Latent Testing Workshop

National Institute of Standards and Technology

April 5 & 6, 2006

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**Topics covered:**  
**A product development & solution delivery**  
**meeting specific customer needs, point of view.**

- **Background**
- **Progressive Matching Methodology?**
- **Setting thresholds and Automatic Decisions**
- **What is next? Concluding Thoughts.**

# What is an Automated Fingerprint Identification System?

- An AFIS is a computer application developed and used as a decision support system, to help improve the operation of a criminal justice information and processing system.
- It is **NOT** a replacement for criminal justice investigation and forensic science know how in the ID Bureau Departments.
- “Lights-out”, “Automatic Decisions”, etc. are not proper terms to be used in this context. And it may be harmful for the industry credibility.
- It is the good old “technology will solve all the problems” and a little bit of hype and immaturity on the side of vendor community, desperate to have a “differentiating feature!”
- **Do you know how your AFIS works? How the Latent Matching works? etc.**

# What are Latent or partial prints Digital Image?

- **Lifted, left over fingerprint impressions via sophisticated forensic science methods which are processed and captured with certified quality scanners or digital cameras.**
- **The processes involved to collect crime scene latent is a non-trivial, established methodology and is the subject of new innovations and techniques which the worldwide forensic labs and academics pursue and share actively.**

# The Science behind the Image Processing, Feature Extraction and Matching:

## What Features we use to match fingerprints?

What are the statistical characteristics or information content of the features used?

“Robust measures”, “weak Measures”

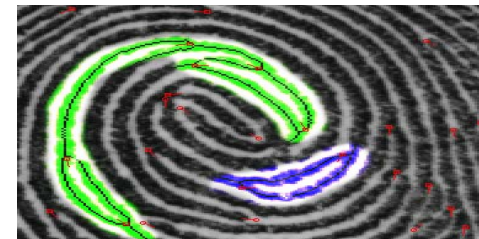
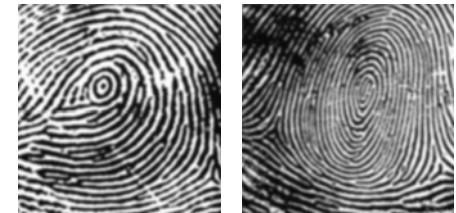
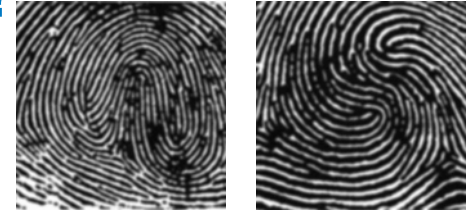
Let’s look at the Fingerprints images:

Forensic Science defines three levels of features in the fingerprint impressions:

–Level one Features, Ridge Flow Patterns Characterizations; example of fine level classification:

–Level two Features: Discrete singular points of the friction ridges, Minutiae, minutiae relationships;

–Level three Features: Characterizations of the friction ridge skin tissue at finer details, pores, incipient ridges, minutiae characterizations.



Incipient Ridges

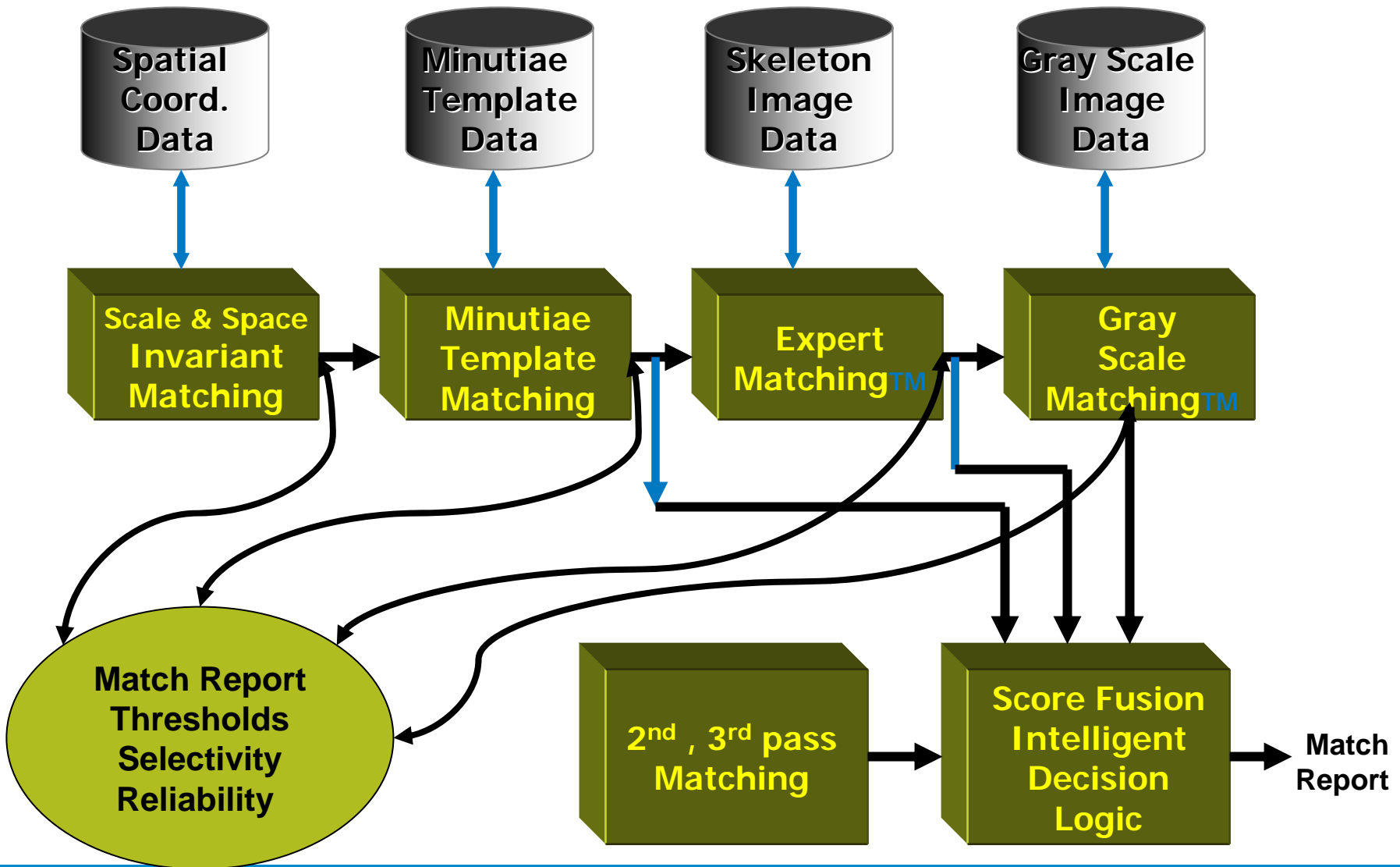


Ridge & Valley Width

# Individualization

- **As the database of people increases the distribution of pattern measures will start overlapping, i.e. more people characteristics will classify to the same class of features**
  - Resulting in no discrimination → loss of matching performance.
- **The more independent features, or detail and discrete features we use:**
  - Will result in better separating the classes → better matching performance → Forensic Expert call it “Individualization”.
- **When Matching fingerprints, specially partial prints which by definition have less features, one has to start by carrying out some basic statistical analysis of each feature or component extracted and used in matching.**
  - Is the pattern or any level one feature exist and measurable, what is the associated confidence or quality measure;
  - How many minutiae are present? what level of each minutiae attributes we have? What is the confidence or quality level for each minutiae?

# Multi-Pass, Multi-Stage Progressive and Fusion Matching Technology



# What is Progressive Multi-Pass Matching ?

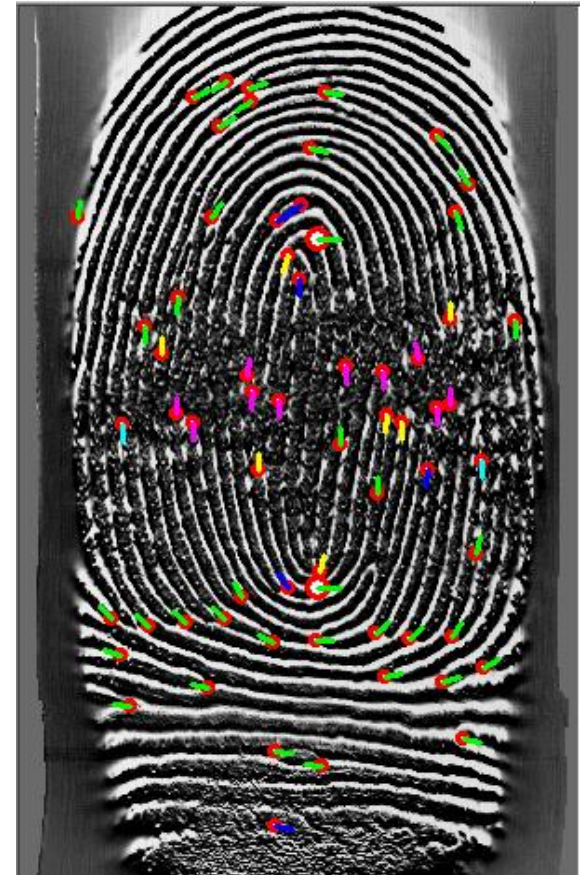
## Reliability/Selectivity Approach

- **Progressive Matching:**
  - Use coarse feature data, small but robust set to select a portion of the database candidates with close to 100% reliability.
  - Use next level finer and more information features to reduce the scope of the data set further, again with close to 100% reliability.
  - Use different set of features, graphical based, topological relationship etc. to re-score and re-sort the match report.
- **Multi-Pass Matching:**
  - Use Minute quality level or confidence level to carry out a complete match. Then add next level lower quality minutiae for a second match pass, etc., use thresholds to stop the process;
  - Use random and well-define minutiae perturbation to run a second complete run.
  - Use flat and rolled match results
  - Auto and manual feature set match reports
- **Fusion:**
  - Use ordinal rank decision analysis, plus,
  - Match score fusion to produce final match scores and match report.



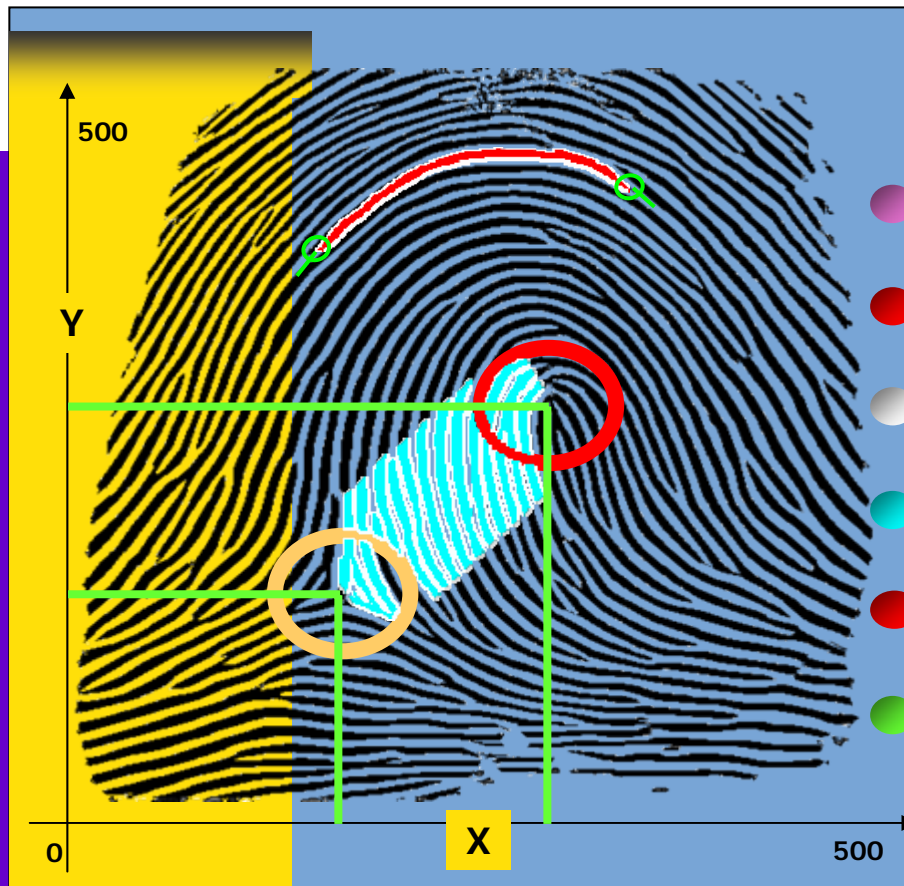
## Minutiae confidence levels, used in the multi-pass matching approach.

The color of minutia tail show its quality : green represents best quality, blue, pink, yellow, light blue, and red colors represent the quality from high to low respectively



# Expert Match™ Processing

## Expert Match Processing



Minutiae Match Score

Core location <297, 309>

Delta location <187, 138>

Ridges:core-delta 16

Similar ridges 7

Ridge Minutiae 27

Total Score

Score

2,000

2,000

2,000

2,000

1,000

1,000

10,000

# Examples of Improved Detection using the Latent Expert Matching™

Old

New

1. 1000582000130006 2020
2. 1004412000210004 1975
3. 1100022000105004 1885
4. 1007612000286006 1865

- 1. f00053966g 5538**
2. 1004412000210004 4462
3. 1000582000130006 4440
4. 1001712000333003 4410

.....

**84. f00053966g**

**1605**



Search Case



Image Information  
Image X: 432 (416) Image Y: 498 (13) (32) Match Score: \*\*

Modified Minutia Information  
Minutia X: \*\* Minutia Y: \*\* Theta: \*\* Score: \*\*

File Case

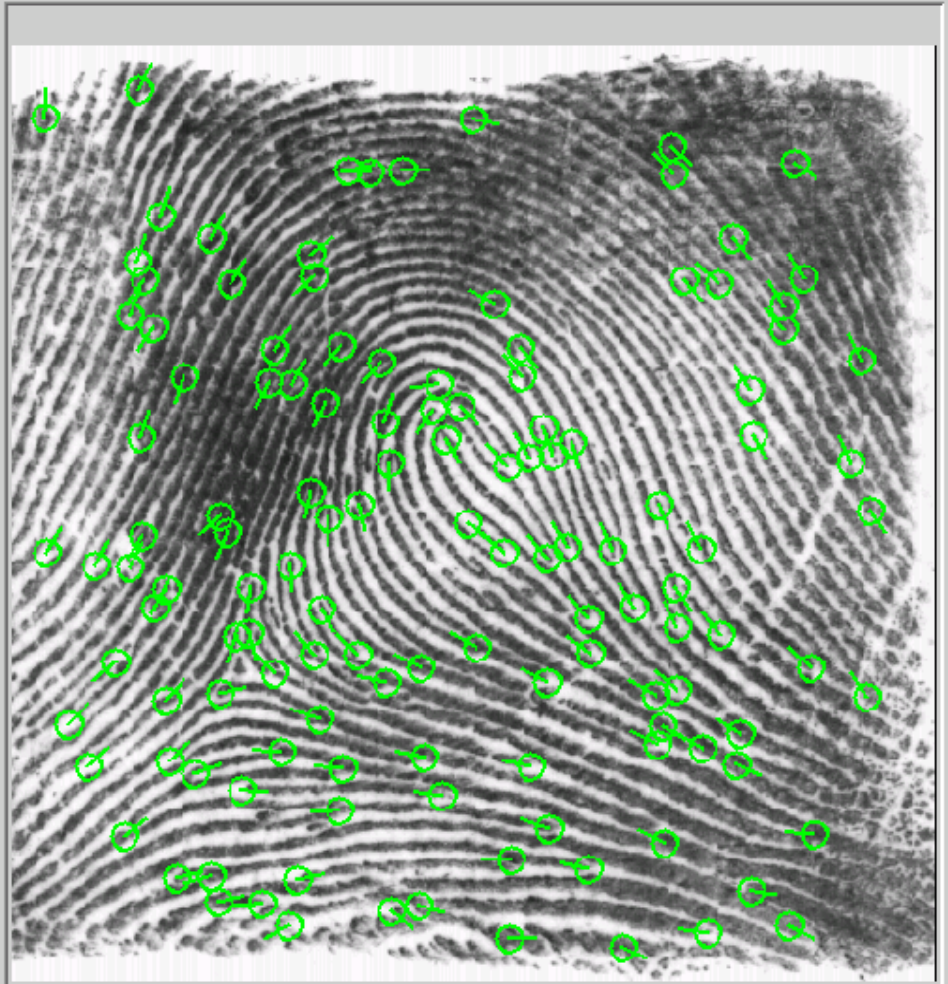


Image Information  
Image X: 467 (450) Image Y: -14 (525) (525) Match Score: \*\*

Modified Minutia Information  
Minutia X: \*\* Minutia Y: \*\* Theta: \*\* Score: \*\*

# Examples of the use of Latent Expert Matching™

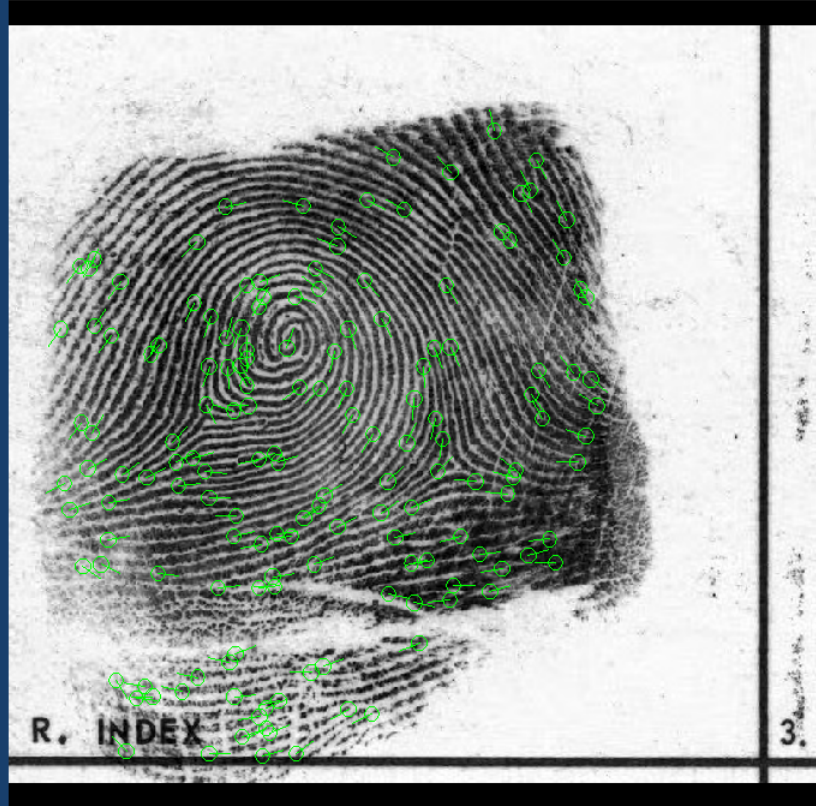
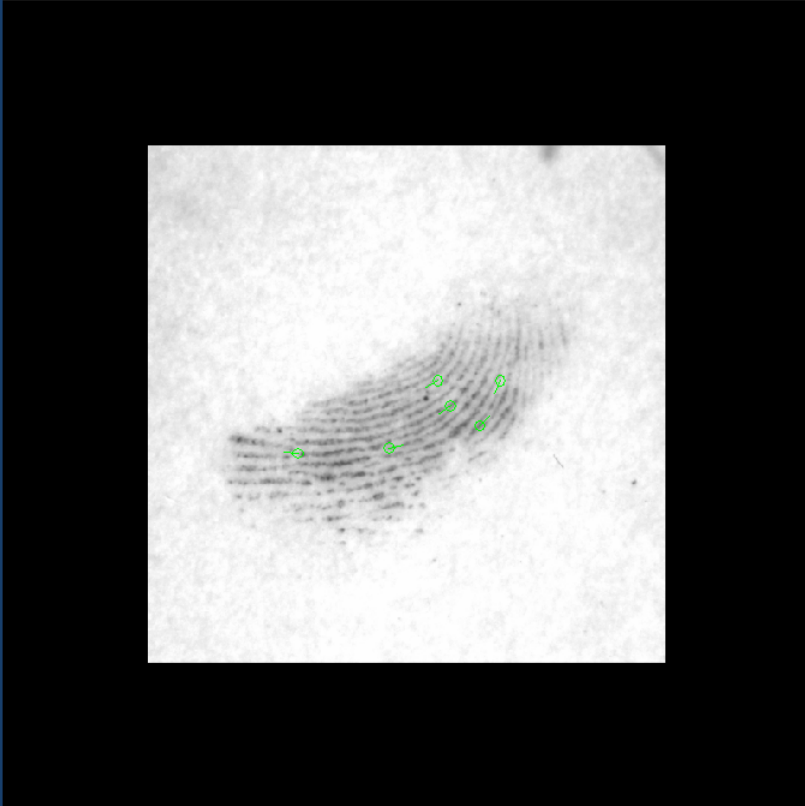
- Search print has 6 minutiae
- The EM score was 15034 from a cold search on background database of 1 million fingers

<b>1. 88800000001</b>	<b>15034</b>
2. 001000010407	6152
3. 6793298	4951
4. 6815546	4804
.....	

Latent Case : 777433330002

Respondent Case : 888000000001

Latent vs. LCF



Display Minutiae

Ident

Non Ident

Save To Charting

Finger: ?

Print: 1

Finger: 2

	Position	ID	Matcher Score
	1	888000000001	15034
	2	001000010407	6152
	3	6793298	4951
	4	6815546	4804
	5	6671169	4751
	6	6818436	4714

Help

Charting

Cancel

< Prev

Next >

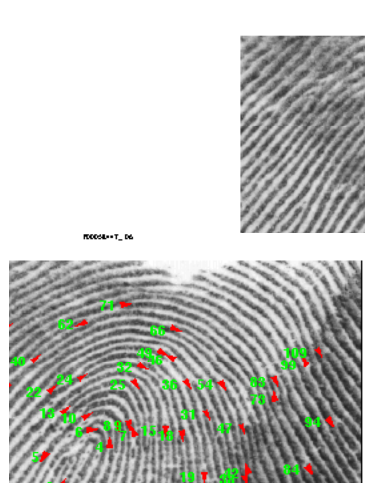
Finish

# Gray Scale Matching™

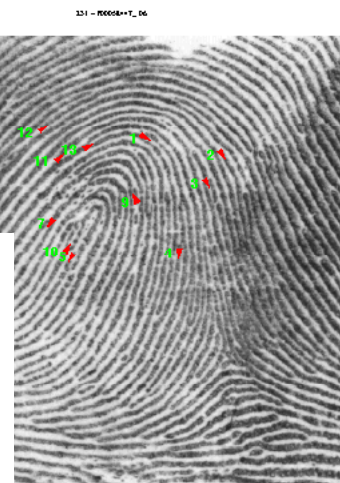
## Minutiae Matching {{x,y,a},...}



Search Print  
with  
Detected  
Minutiae



File Print with Detected Minutiae




File Print  
with  
Matched  
Minutiae

# Examples of Gray Scale Matching™ and Match Score Fusion Algorithm

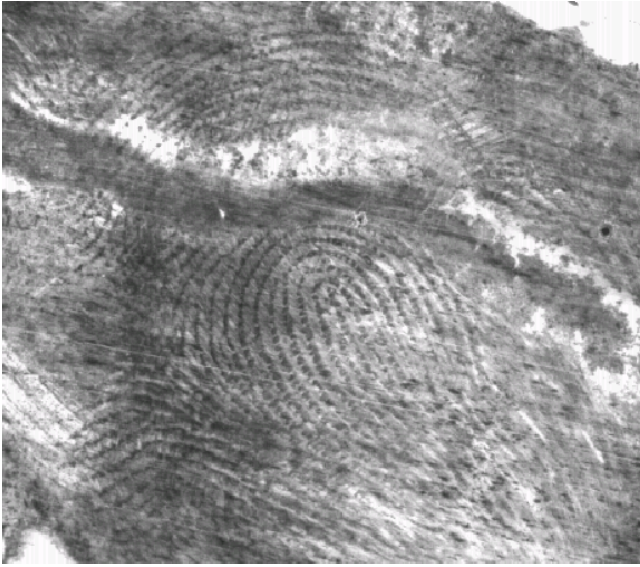
Latent to tenprint search in 1M Background database: Case# 370000005103\_01 moved up from position 106 to the first position in the match report

.			1) 001000014711_07	3190
.			2) la444000000304_06	2586
102)	617000017300_07	2180	3) 617000015775_06	2395
103)	617000018595_06	2175	4) 617000015937_07	2334
104)	617000018800_10	2175	5) ff01316_02	2155
105)	617000014443_06	2170		
106)	001000014711_07	2170		
.				
.				
.				





# The Search Print and the top three respondents



# Concluding Thoughts.

- **Latent Processing and Matching is a critical functionality of an AFIS.**
- **Rank order, (% in the top position of the match report, or % in the top five position) is the best measure for comparing the accuracy performance.**
- **Multi-Stage, Multi-pass, Progressive Matching and match result fusion with Dynamic and static thresholds to optimize the Reliability & Selectivity is the most common solution.**
- **The matching process outcome is a most likely match candidates (one or more) and **NOT** a HIT or No-HIT decision.**
- **SDK testing and ROC (FAR & TAR) measures are **NOT** the right approach to evaluating the accuracy performance.**

# Next Steps

- **There is nothing proprietary about the fingerprint feature data. The innovation is in techniques and algorithms to detect and use the data.**
- **Complete the CDEFF, amend/release as part of the ANSI/NIST-ITL 2006(yes, or 07!).**
- **Customers, Users require compliance to the Standard feature and retire REFS, ULW.**
- **Fix the confusion on the performance measures; TAR=the presence of matching print in the top two positions in the match report!!**
- **Image quality measure for latent based on the CDEFF defined signal quantity and quality strength, NOT PERFORMANC**
- **Work on test data sets: NIST27 data set is a good start, need expansion, and larger set to facilitate testing and statistically relevant outcome.**



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***Dr. Bavarian is one of the pioneers and industry leading authority in the field of Fingerprint Biometric Identification with over 26 years of management and R&D experience in industry and academics.***

***Currently he is in charge of the business development strategy, partnership and technology acquisition for the Motorola Biometrics business unit.***

***In the last 14 years, Dr. Bavarian led the development of two Automated Fingerprint Identification Systems, products generations with over 100 large scale deployments. Prior to Motorola, Dr. Bavarian was a professor in the Department of Electrical and Computer Engineering at the University of California, Irvine for eight years, where he conducted original research and published 100 technical papers and received several awards for outstanding research and distinguished teaching.***

***Dr. Behnam Bavarian received his Ph.D. in Electrical and Computer Engineering from The Ohio State University, Columbus Ohio.***