INTEGRATING RARE MINUTIAE IN GENERIC FINGERPRINT MATCHERS FOR FORENSICS

RAM P. KRISH, JULIAN FIERREZ, DANIEL RAMOS

BIOMETRIC RECOGNITION GROUP - ATVS

ESCUELA POLITECNICA SUPERIOR

UNIVERSIDAD AUTONOMA DE MADRID, SPAIN

7th IEEE International Workshop on Information Forensics and Security (WIFS) 2015. Rome, Italy

November 2015

OUTLINE

- Introduction
  - Forensic Fingerprints
  - Latent Fingerprint Technology Evaluations
  - Challenge Addressed in this Work
- Systems and Database
- Contribution of this work
  - Extended Fingerprint Feature Sets
- Conclusions & Future Work

INTRODUCTION

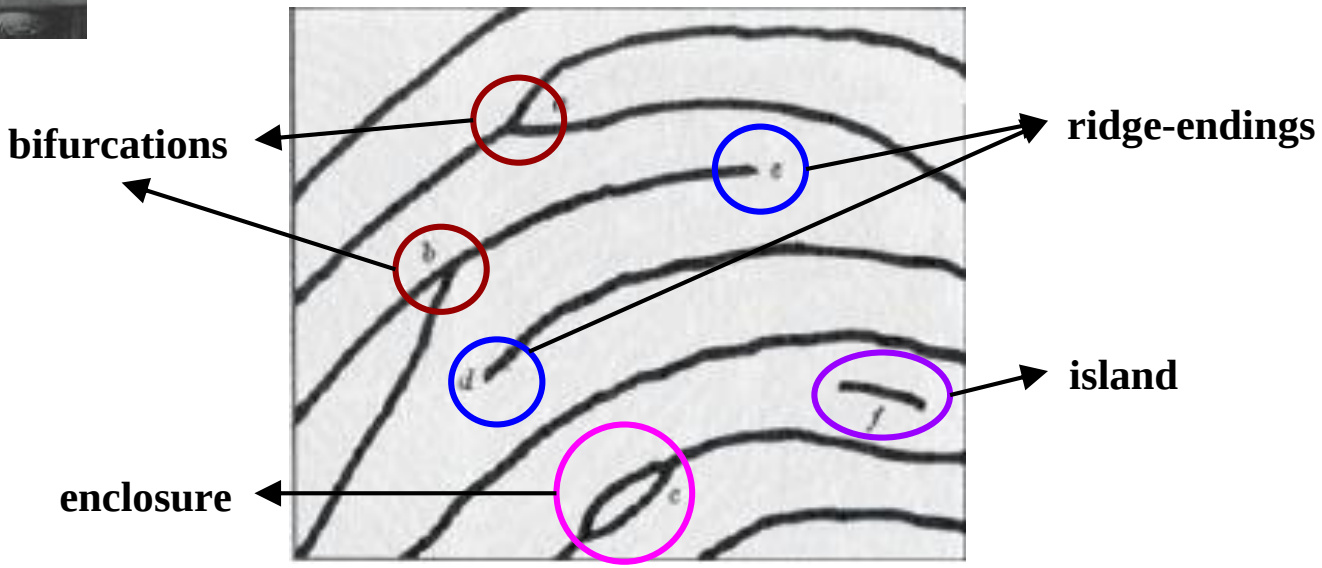
Types of Evidences

ForensicToxicology
DigitalEvidence
Impression
ForensicAnthropology
Latent
Fingerprints
Forensics
Evidence
ForensicPathology
DNA
QuestionedDocuments
ForensicDentistry
TraceEvidence
PatternEvidence
ControlledSubstances

INTRODUCTION

Galton Details : More specific in criminology

- Francis Galton coined the term ***minutiae*** **(discriminant features).**
- Described fingerprint comparison based on minutiae.
- Galton's method first used in a homicide case in India in 1897.
- Conducted studies on sufficiency of minutiae.



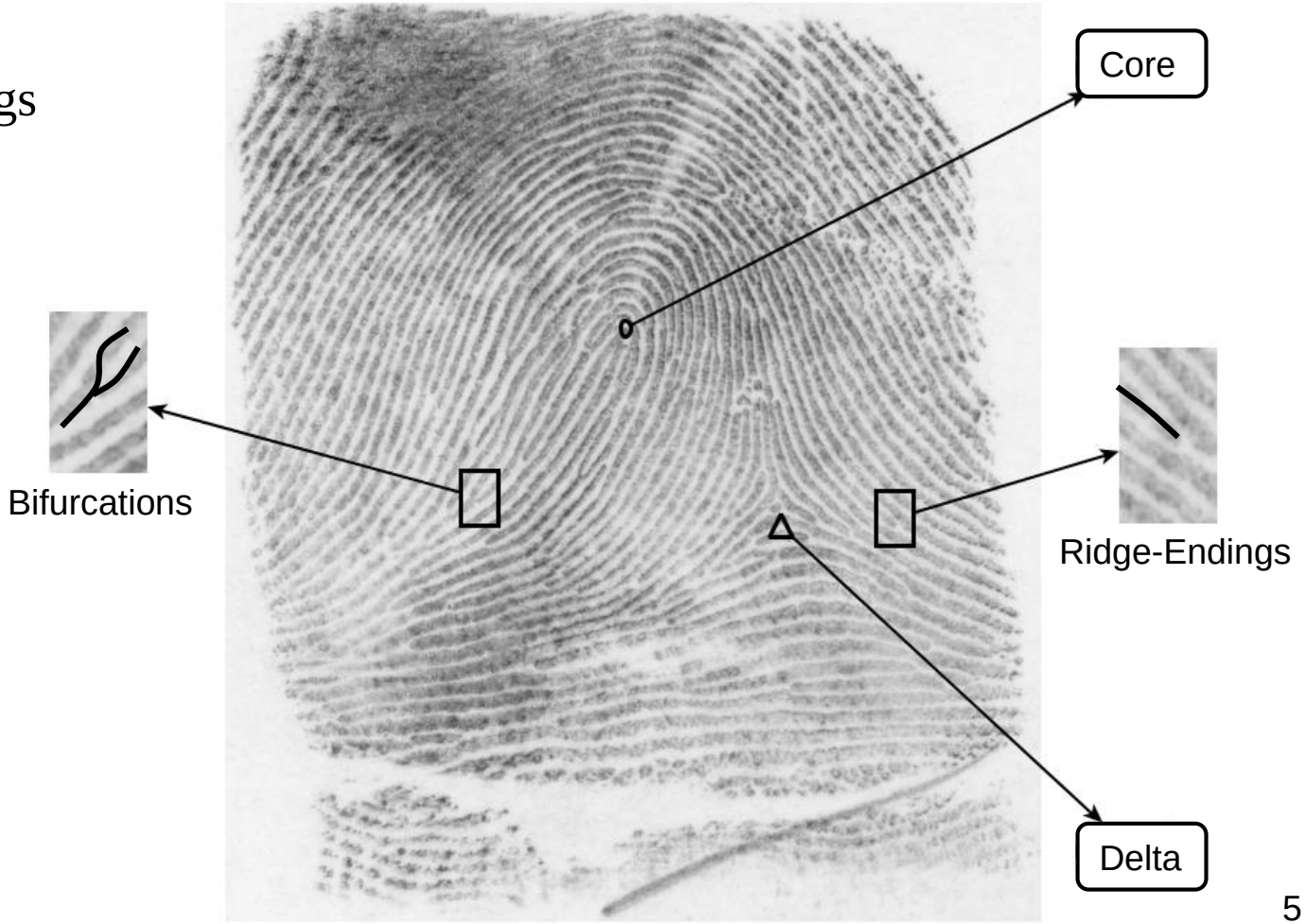
Finger Prints. Francis Galton **Macmillan,** *1892*

INTRODUCTION

Common fingerprint features used for comparisons

Typical minutiae:

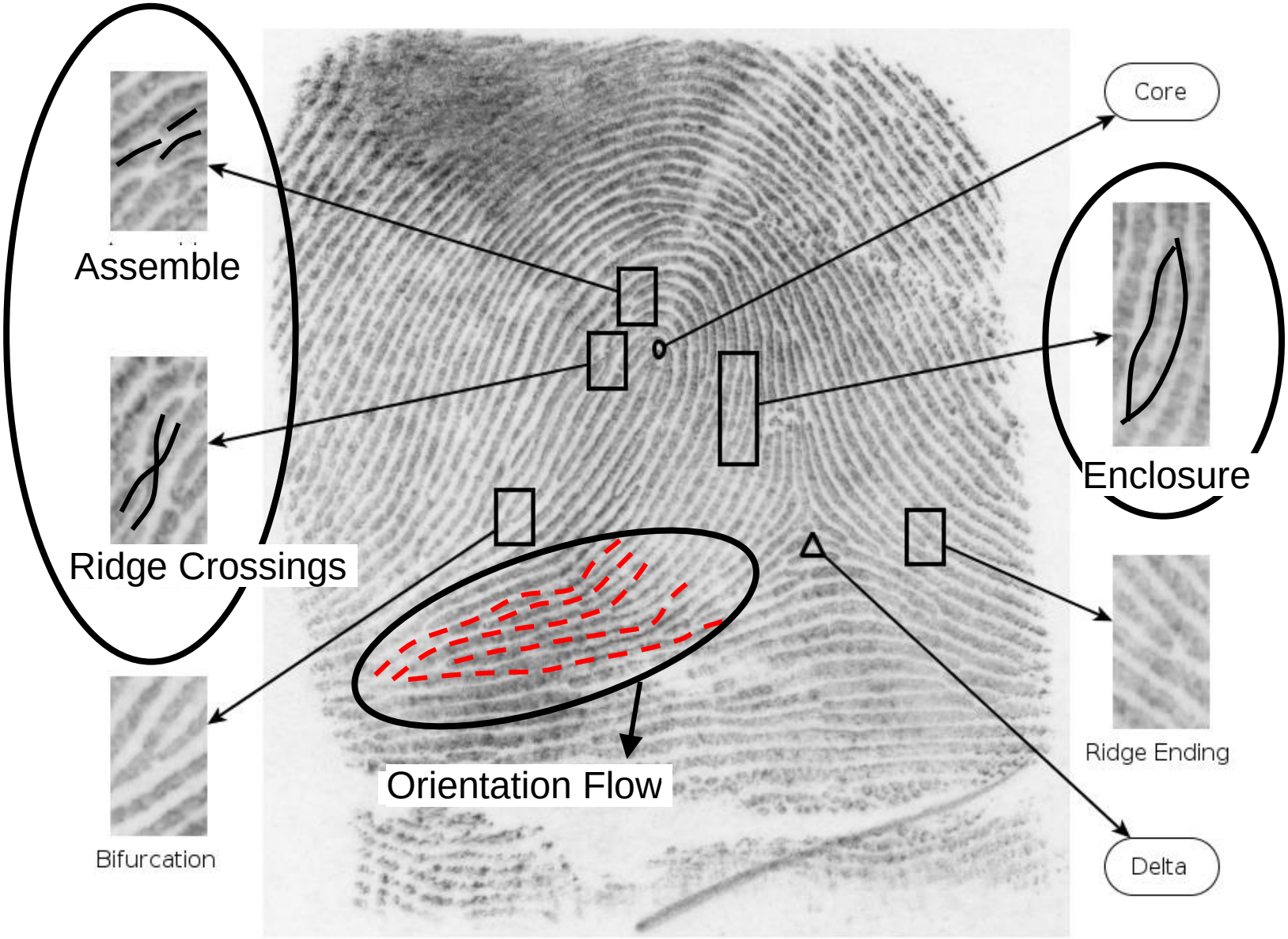
- Ridge-Endings
- Bifurcations



Singular points:

- Core
- Delta

Extended Feature Sets



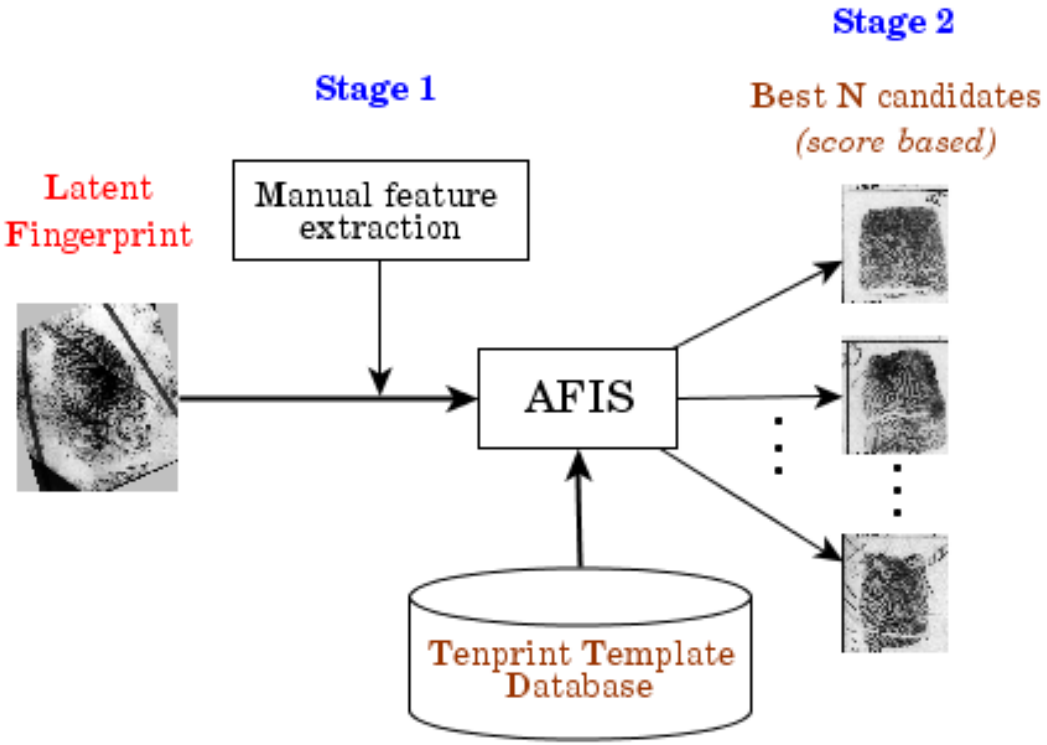
INTRODUCTION

Automated Fingerprint Identification Systems (AFIS)

- Project to develop AFIS started in early 1960.
- Initiated by United States, United Kingdom, France and Japan.
- Used to obtain a shortlist of possible suspects from criminal database.
- This is followed by forensic friction ridge examination.

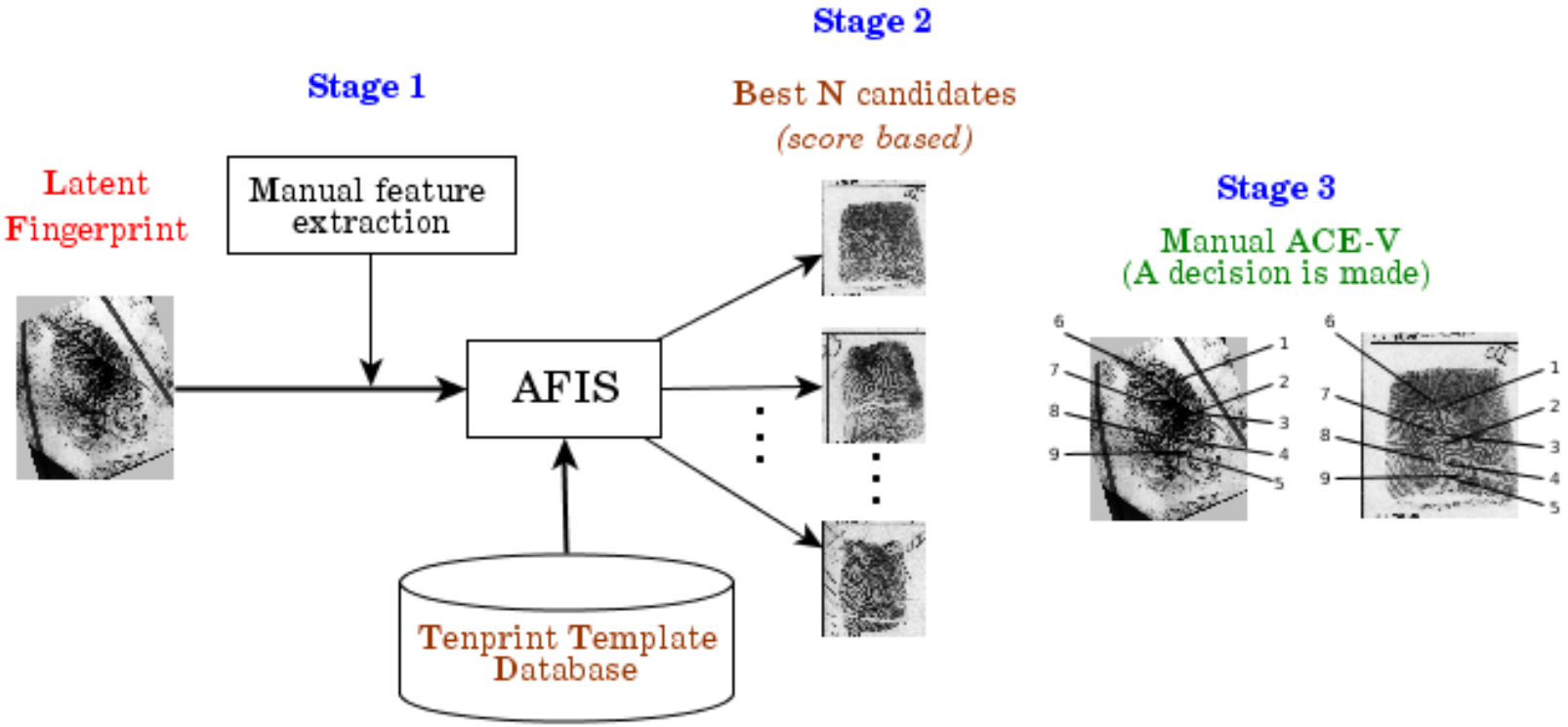
INTRODUCTION

Fingerprint Examination Process



INTRODUCTION

Fingerprint Examination Process



INTRODUCTION

Latent Fingerprint Matching Evaluations

Lights-Out System

- **Feature Extraction** & **Matching** are *automatic*.

- NIST (National Institute of Standards and Technology) evaluation of AFIS in Lights-Out mode.
  - Evaluation of Latent Fingerprint Technology (**ELFT**)

- Companies: NEC, Cogent, Motorola, L1-Identity, etc.

Phase of ELFT	Database size	Rank-I Accuracy
Phase-I (2007)	100 latents vs 10,000 rolled prints	80.0%
Phase-II, Evaluation-I (2009)	835 latents vs 100,000 rolled prints	97.2%
Phase-II, Evaluation-II (2012)	1,114 latents vs 100,000 rolled prints	63.4%

INTRODUCTION

Latent Fingerprint Matching Evaluations

Lights-Out System

- Studies show that not all qualities of latent fingerprints benefits from automated procedures.
- Manual intervention is still needed.
- It is a usual practice in friction ridge examination procedures where forensic examiner manually extracts the discriminant features.

INTRODUCTION

Latent Fingerprint Matching Evaluations

Semi Lights-Out System

- **Feature Extraction** : *manual*, involves Extended Feature Sets (**EFS**)
  Matching : *automatic*

- NIST evaluation of AFIS in Semi Lights-Out mode
  Evaluation of Latent Fingerprint Technology (**ELFT-EFS**)

- Companies: Sagem, NEC, Cogent, Sonda, Warwick.

Phase of ELFT-EFS	Database size	Rank-I Accuracy
Evaluation-I (2011)	1,114 latents vs 1,000,000 rolled & 1,000,000 plain prints	66.7%
Evaluation-II (2012)	1,066 latents vs 1,000,000 rolled & 1,000,000 plain prints	71.4%

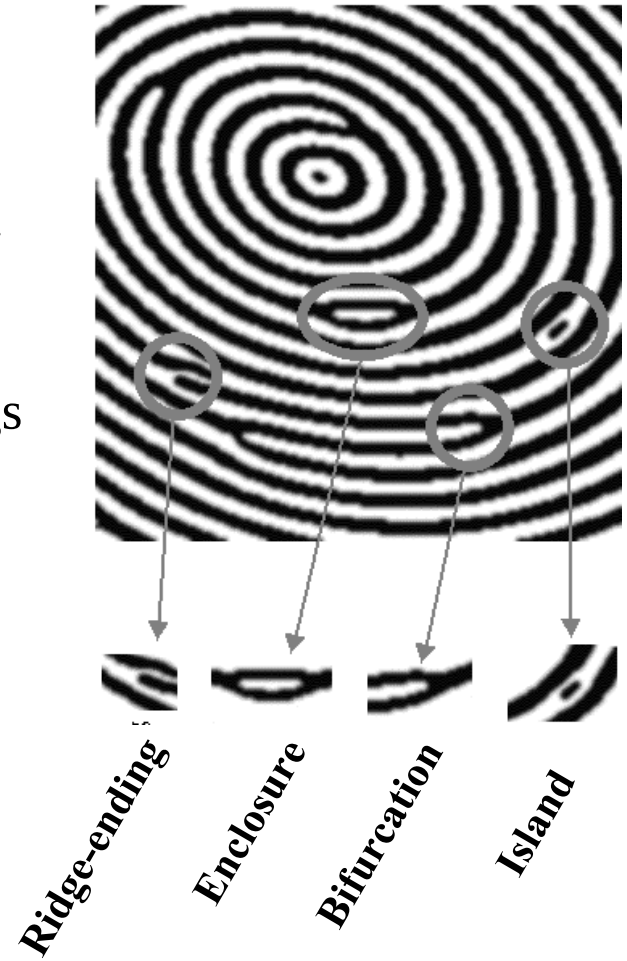
Challenge Addressed in this Work

CHALLENGE

Incorporating the manually extracted extended fingerprint feature sets to improve the performance of minutiae-based matchers.

- Studies show that manual interventions is inevitable in forensic fingerprint evaluations.
- Most minutiae-based matchers uses only typical minutia features such as ridge-endings & bifurcations.

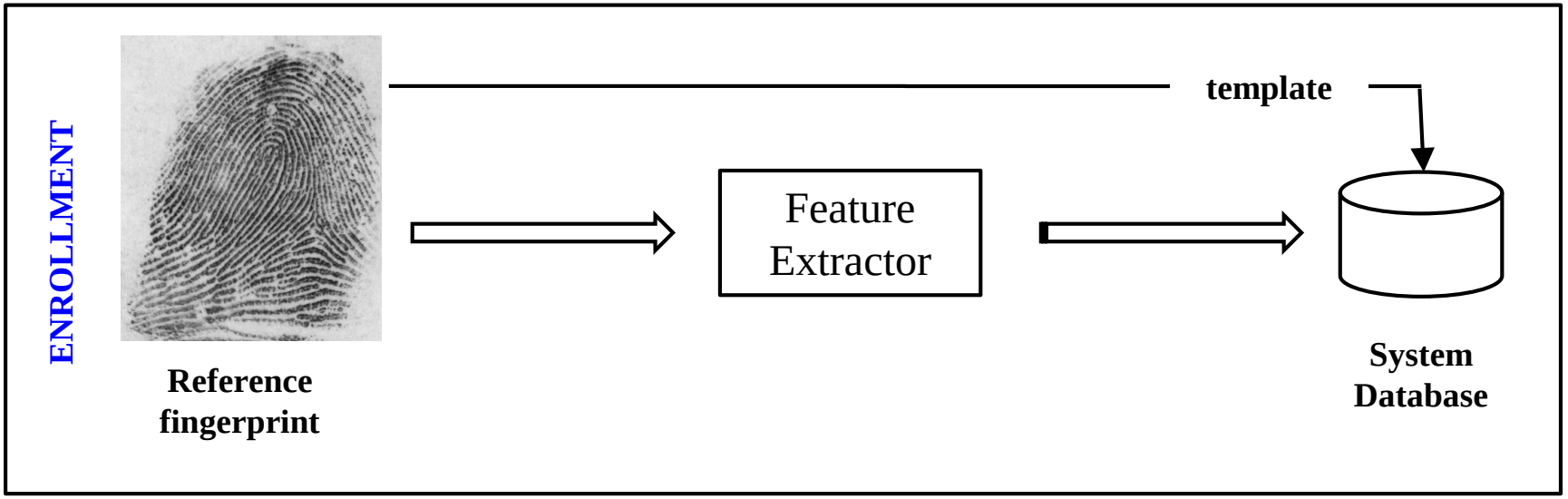
How to use rare minutiae features in typical minutiae matchers?



SYSTEMS & DATABASE

SYSTEMS

General purpose Minutiae-based Fingerprint Recognition System



SYSTEMS AND DATABASE

Fingerprint Matchers

- NIST-Bozorth3 (publicly available)
- VeriFinger (commercial, not public)

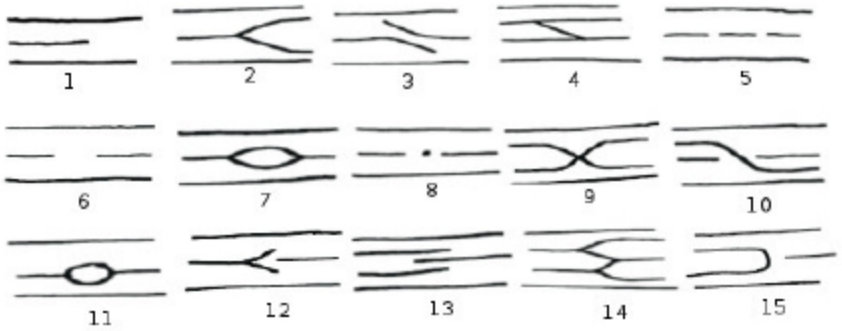
NIST : National Institute for Standards and Technologies

Forensic Database

- Guardia Civil Database (GCDB)
  - Contains 268 latent and corresponding tenprints
  - Average number of latent minutiae: 13
  - Average number of tenprint minutiae: 125
  - Contains rare minutia features, manually extracted.

SYSTEMS AND DATABASE

Guardia Civil Database (GCDB)



Rare minutia features present in GCDB

No	Minutiae type	No	Minutiae type	No	Minutiae type
1	Ridge Ending	6	Interruption	11	Circle
2	Bifurcation	7	Enclosure	12	Delta
3	Deviation	8	Point	13	Assemble
4	Bridge	9	Ridge Crossing	14	M-structure
5	Fragment	10	Transversal	15	Return

SYSTEMS AND DATABASE

Guardia Civil Database (GCDB)

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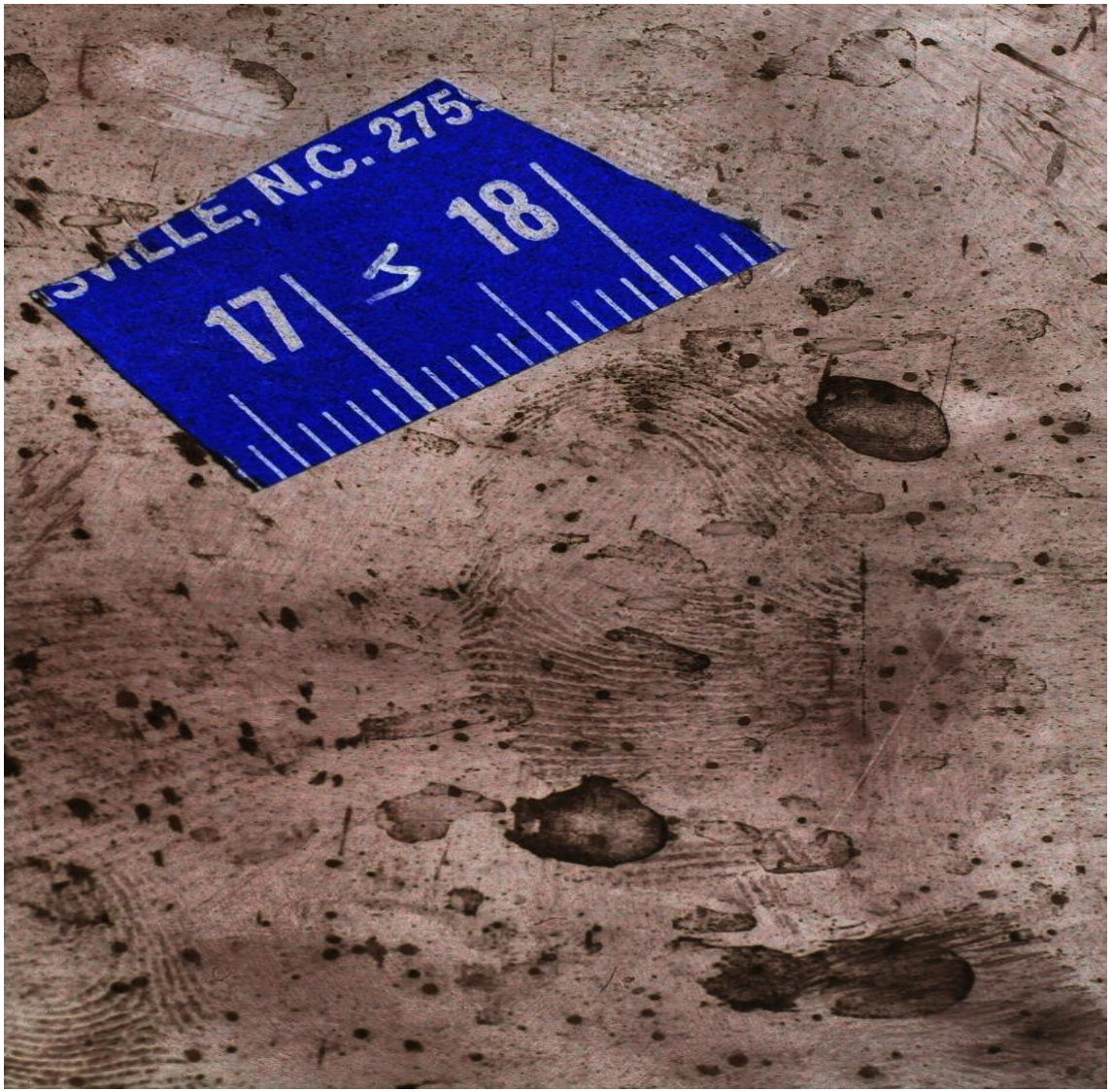
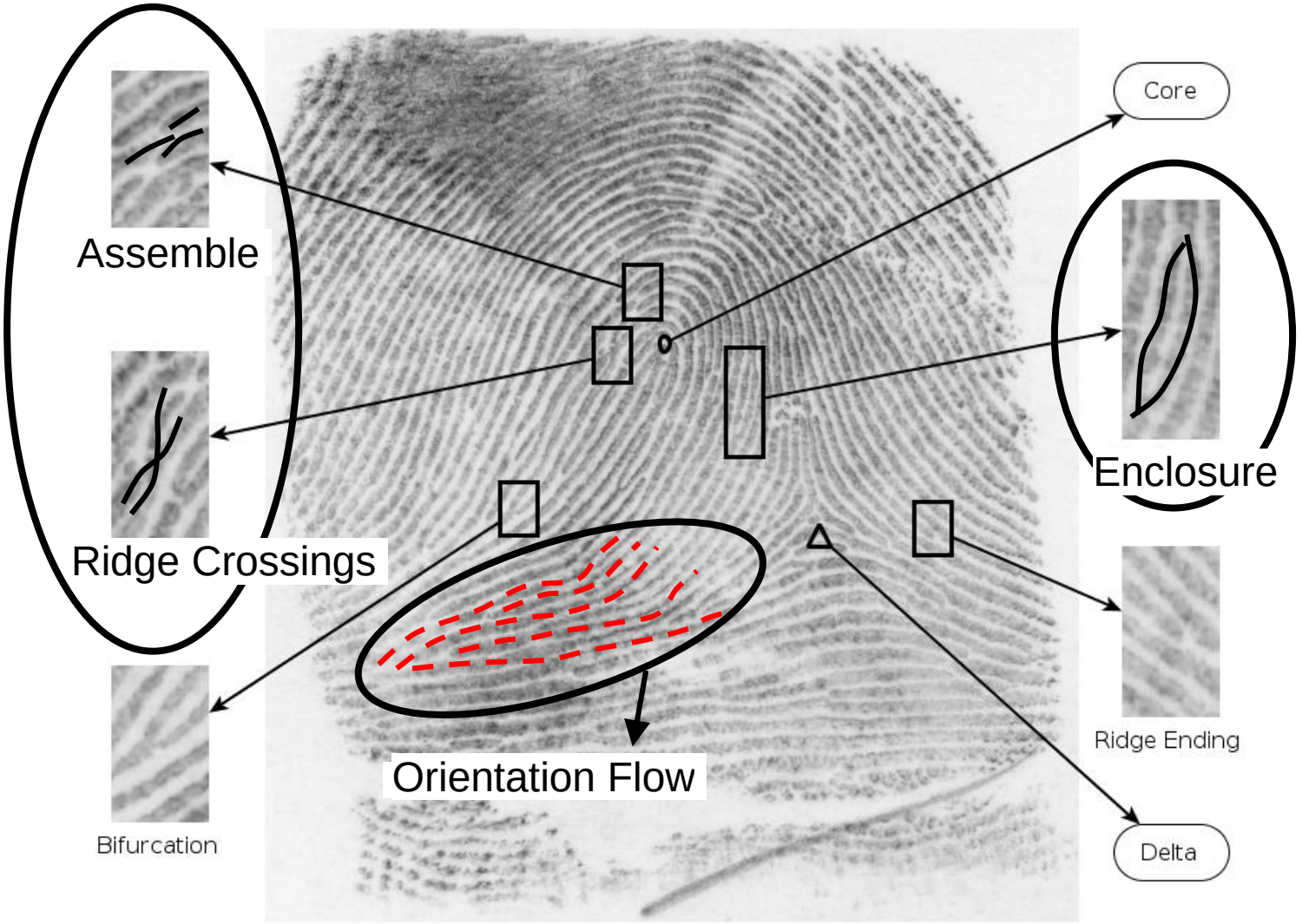


INCORPORATING EXTENDED FEATURE SETS

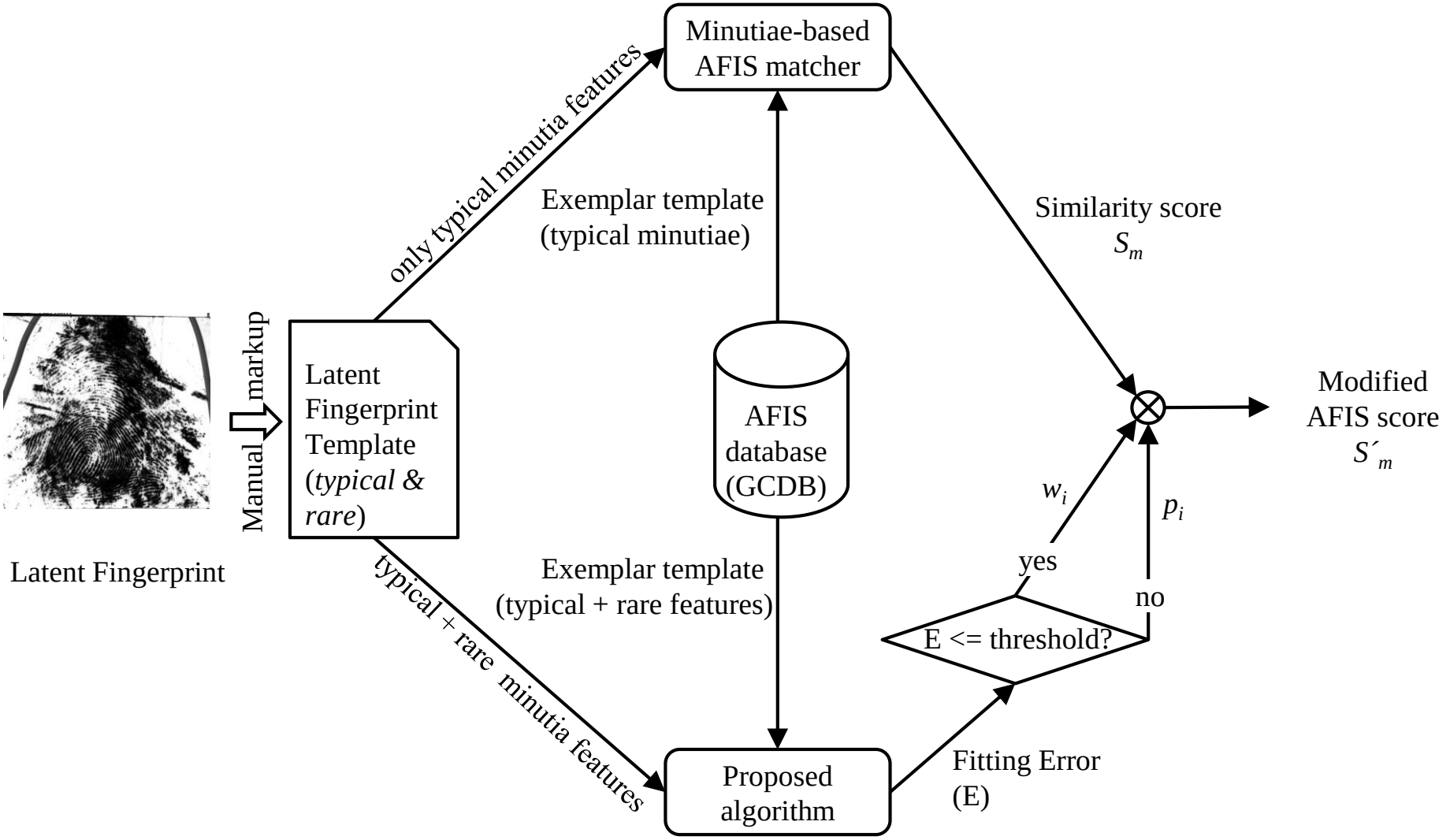
(Rare Minutiae)

Extended Feature Sets



EXTENDED FEATURE SETS

BLOCK DIAGRAM OF SYSTEM DEVELOPED



EXTENDED FEATURE SETS

Proposed algorithm:

Stage 1

- Establish one-to-one correspondence between latent minutia set (L) and tenprint minutiae set (M) by superimposing the rare-minutia feature.
- Minutiae pairs which are close enough are considered mated pairs.
- To compensate for rotational alignment, we rotate the latent in the range [-45º, +45º].
- Optimal rotation is one for which the average sum of distance between closest pairs is minimum.
- Once correspondence is established, we find least square fitting error ($E^{L,Ms}$) to transform the latent minutia points (L) and subset of tenprint minutia points (M_s) for affine transformation.

EXTENDED FEATURE SETS

Proposed algorithm:

Stage 2 : Weighted scores

- S_m is the similarity score generated by reference minutiae-based matcher.
- We obtain the modified similarity score S'_m as follows:

$$S'_m = \begin{cases} S_m \times w_i, & \text{if } E^{L,Ms} \leq E \quad \text{(reward the score)} \\ S_m \times p_i, & \text{otherwise} \quad \text{(penalize the score)} \end{cases}$$

$$\text{if } E^{L,Ms} \leq E \Longrightarrow \text{comparison is a match.}$$

$$\text{if } E^{L,Ms} > E \Longrightarrow \text{comparison is a non-match.}$$

Extended Feature Sets

Statistics of rare minutia features

92% of minutiae are of **typical** category

More **rare** the feature is, **higher** the **penalty** or **reward** to the similarity score.

No	Minutiae Type	Probability (p_i)	Weight ($w_i = -\log_{10} p_i$)
1	Ridge-ending	0.5634	0.2492
2	Bifurcation	0.3620	0.4413
3	Deviation	0.0015	2.8294
4	Bridge	0.0024	2.6253
5	Fragment	0.0444	1.3523
6	Interruption	0.0021	2.6833
7	Enclosure	0.0204	1.6896
8	Point	0.0036	2.4492
10	Transversal	0.0003	3.5284

R. P. Krish, J. Fierrez, D. Ramos and R. Wang, "On the importance of rare features in AFIS-ranked latent fingerprint matched templates", in Proc. 47th IEEE ICCST, Medellin, Colombia, October 2013

Extended Feature Sets

Database used:

- Guardia Civil Database (GCDB)
- 268 pairs of latents & tenprints
- Contains rare minutiae types
- Comparisons: 268 match scores; 268 x 267 non-match scores

Matchers used:

- NIST Bozorth3
- VeriFinger SDK

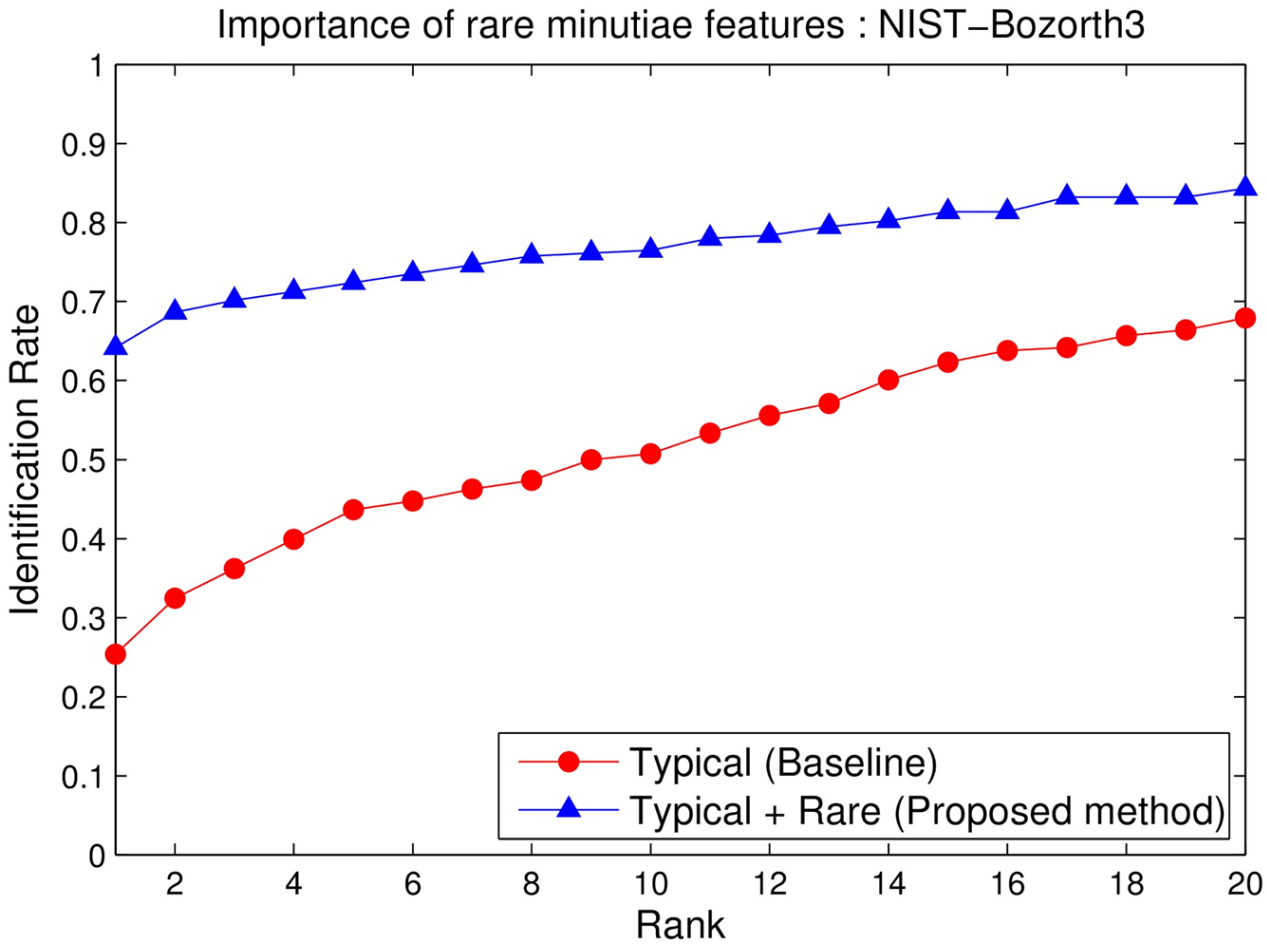
Extended Feature Sets

Two configurations were compared in the experiments:

- Typical (Baseline) : Only ridge-endings and bifurcations were used.
- Typical + Rare (Automatic) : Similarity scores of minutiae matchers were modified based on the fitting error proposed in our algorithm.

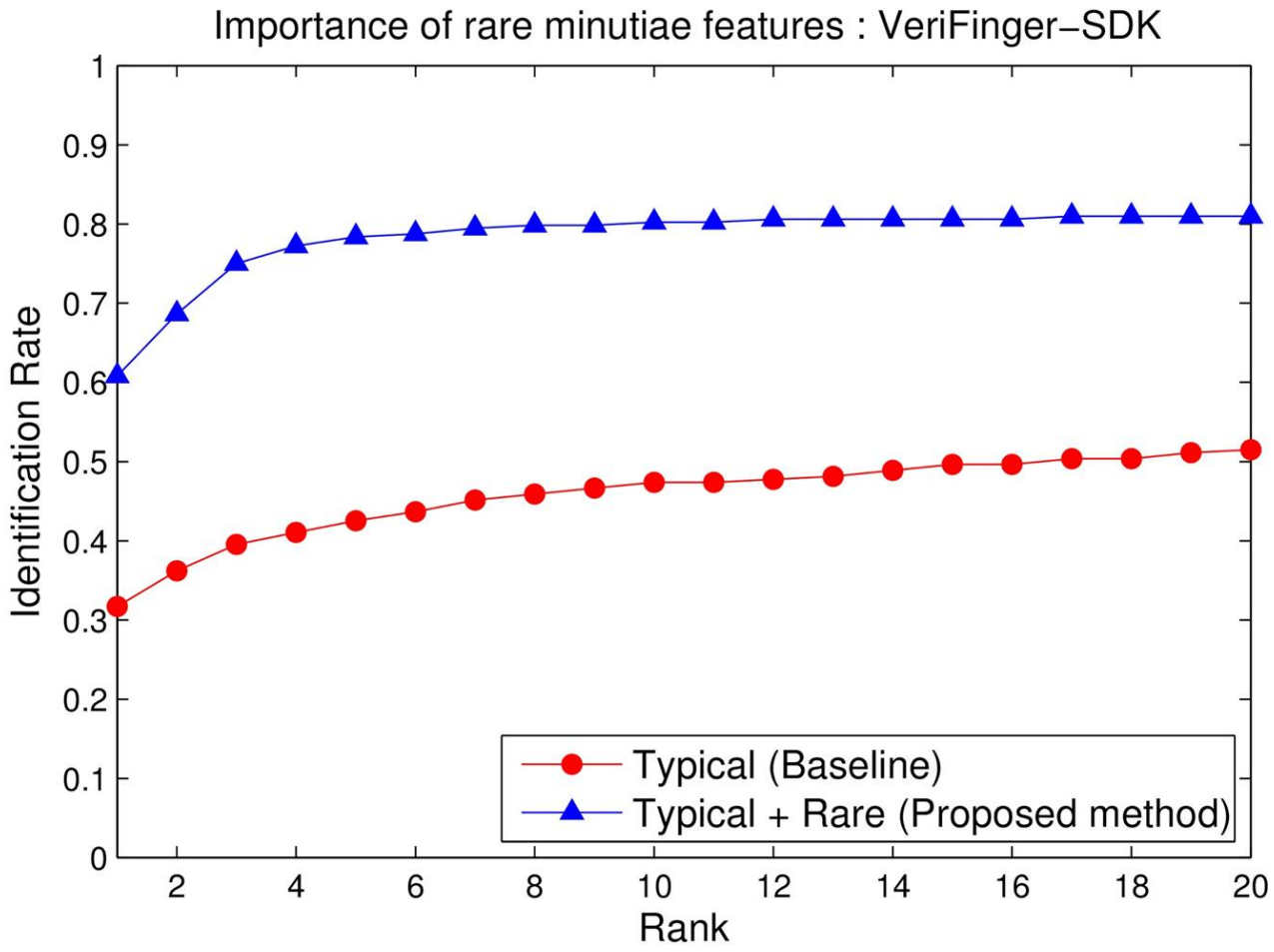
EXPERIMENTS

NIST-Bozorth3



EXPERIMENTS

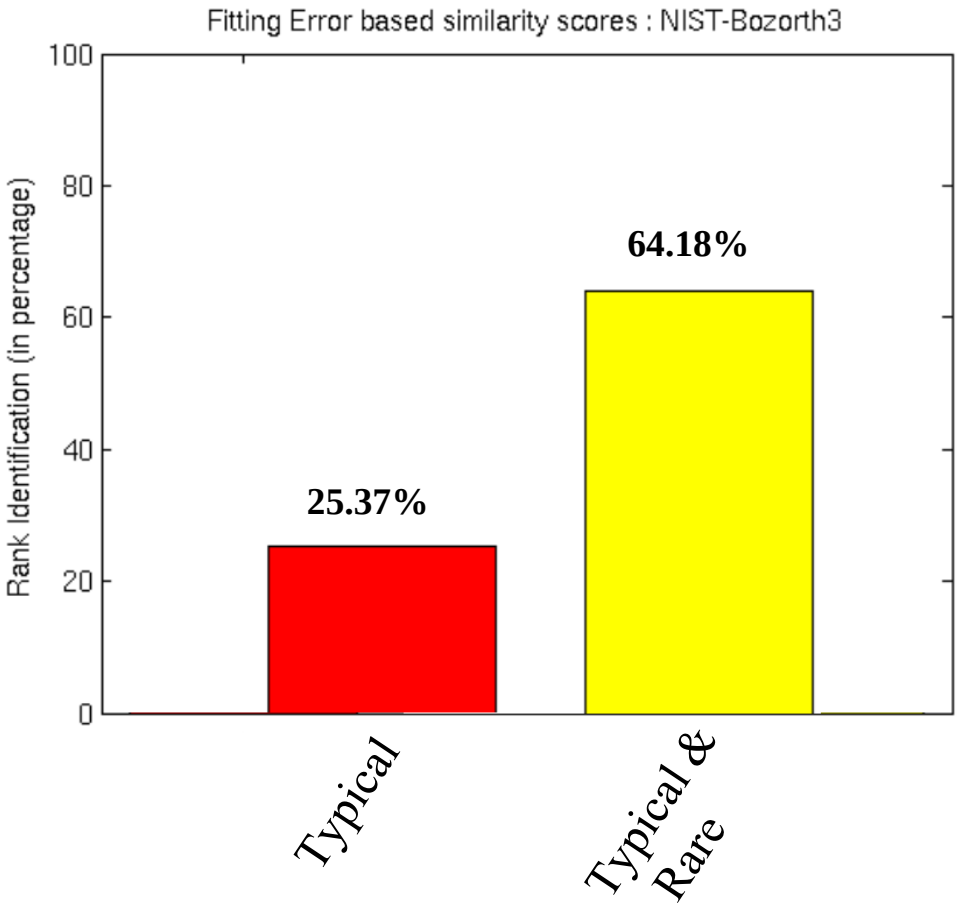
VeriFinger-SDK



EXPERIMENTS

NIST-Bozorth3

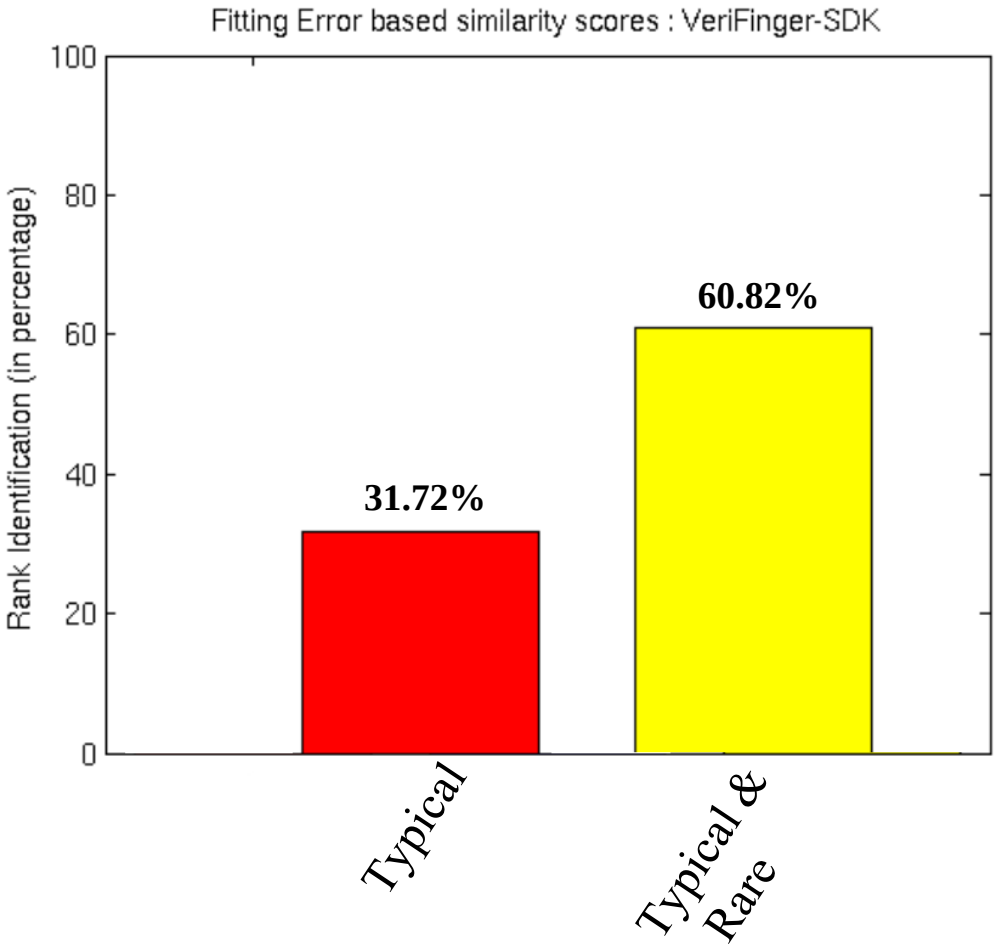
Rank-1 Identification accuracy for various categories of comparisons.



EXPERIMENTS

Verifinger-SDK

Rank-1 Identification accuracy for various categories of comparisons.



CONCLUSIONS & FUTURE WORK

CONCLUSIONS

Use of Extended Feature Sets

- Adapting existing typical minutiae-based matchers to incorporate EFS (rare minutiae features) significantly improves rank identification accuracies.
- We developed a specific algorithm to align latent minutiae pattern and tenprint minutiae pattern based on rare minutiae features.
- Presented population statistics about rare minutiae feature in realistic forensic database.

FUTURE WORK

Use of Extended Feature Sets

- Algorithm to extract rare-minutiae from high resolution fingerprint image.

- Instead of entropy-based measure, use other techniques to reward the similarity scores of reference minutiae-matcher.

- Develop Likelihood Ratio based Evidence Evaluation models using AFIS scores which includes rare minutiae.

THANK YOU