Crowd Powered Latent Fingerprint Identification: Fusing AFIS with Examiner Markups

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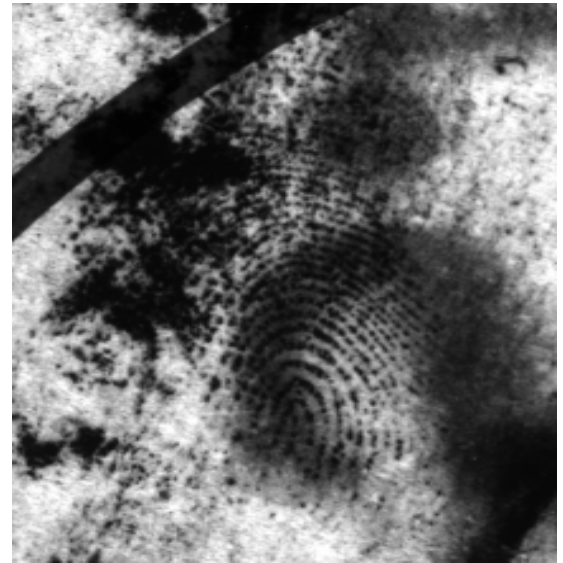
State of the art

Rolled   Plain   Latent

- Lights-out rank-1 hit rate
  - Plain: 99.3%
  - Latent: 67.2% (70.2% with image + markup)

[1] C. Watson, G. Fiumara, E. Tabassi, S. L. Cheng, P. Flanagan, W. Salamon. Fingerprint Vendor Technology Evaluation, NISTIR, 8034, 2012.
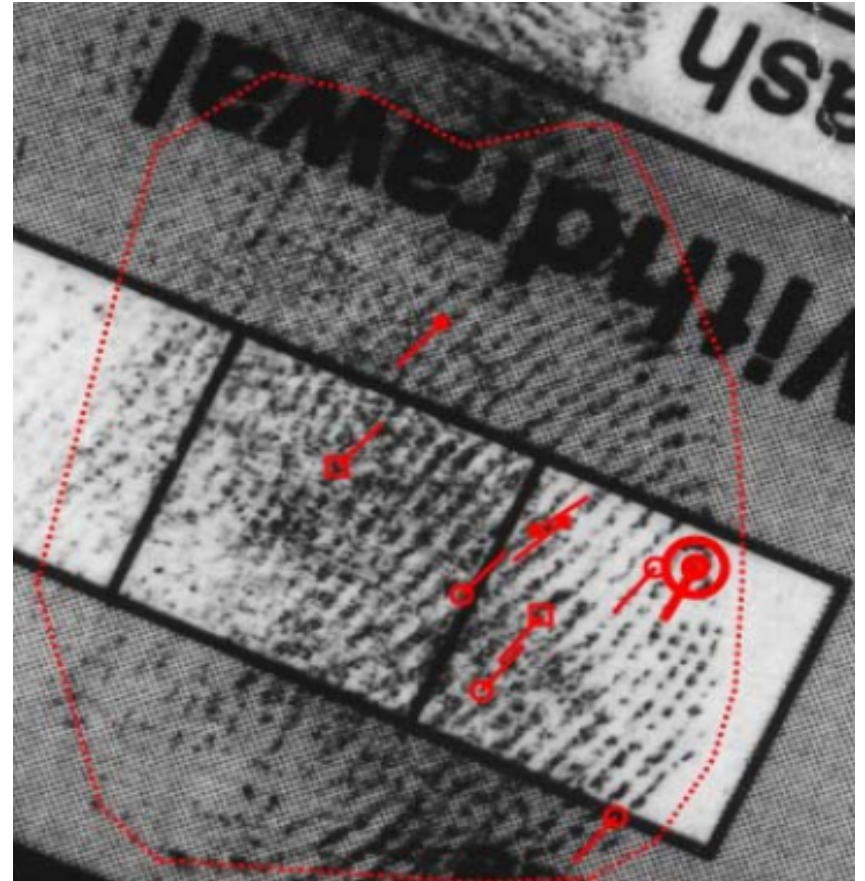[2] M. Indovina, V. Dvornychenko, R. Hicklin, and G. Kiebuzinski. ELFT-EFS Evaluation of Latent Fingerprint Technologies: Extended Feature Sets [Evaluation# 2], NISTIR, 7859, 2012.

Motivation
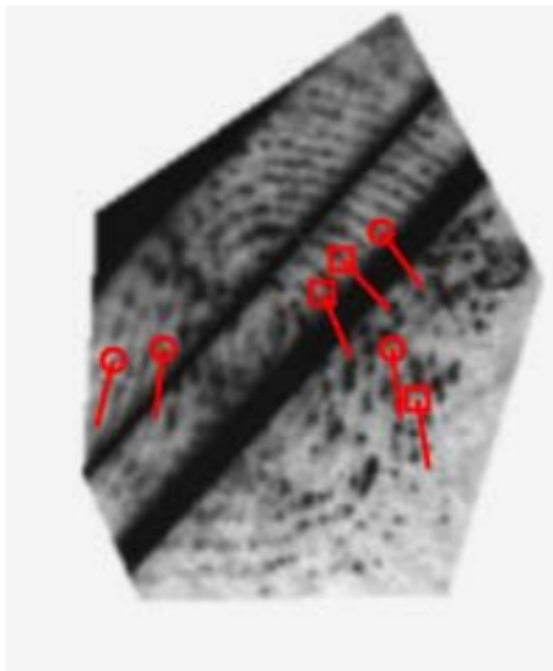
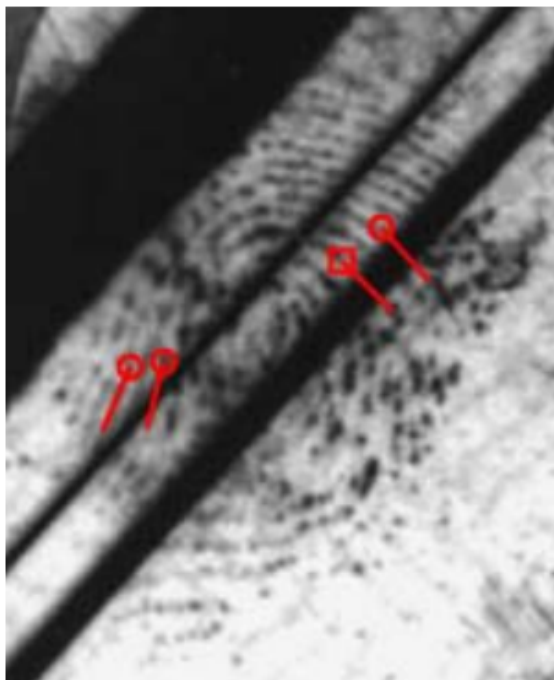- Different examiners provide different mark ups
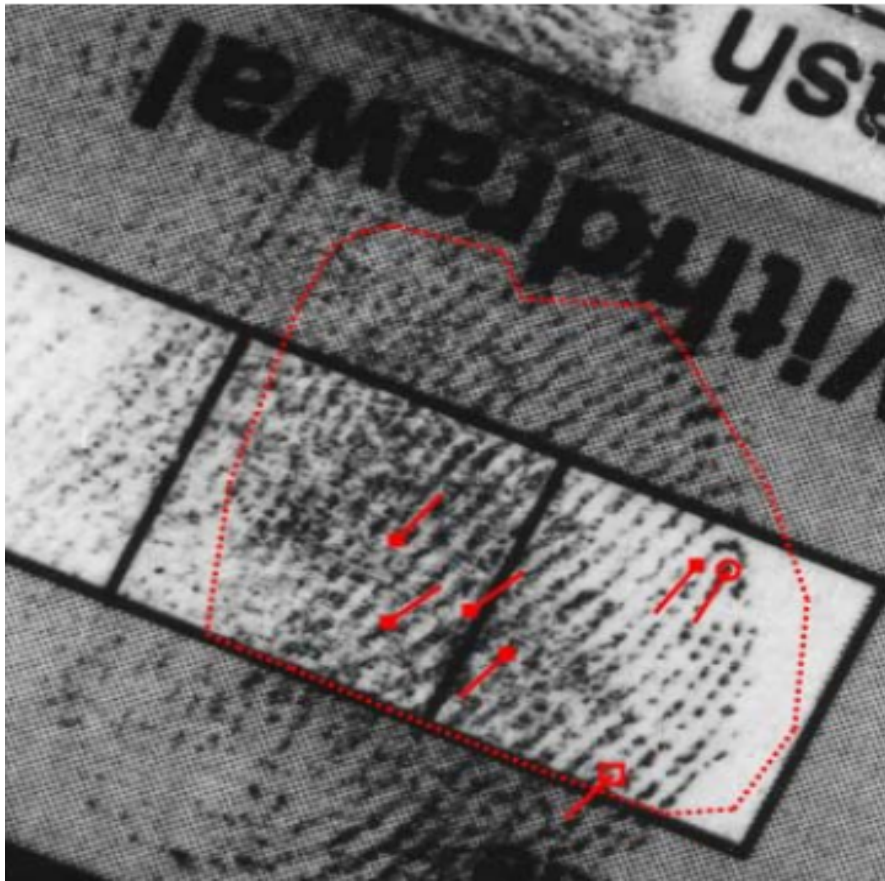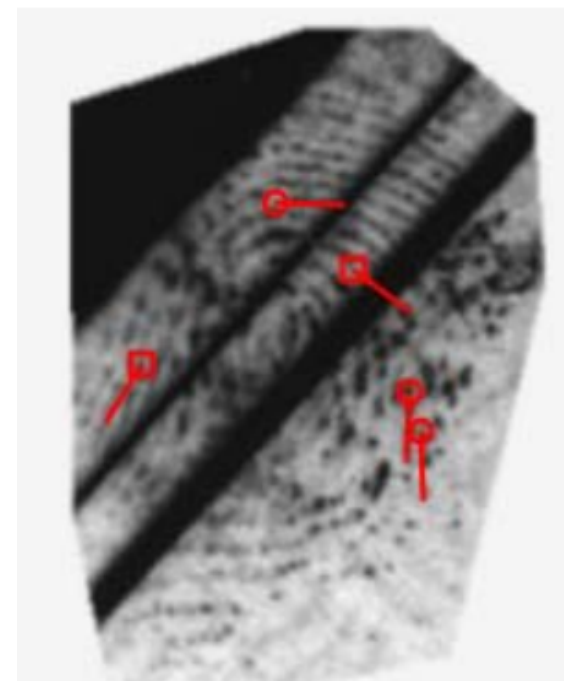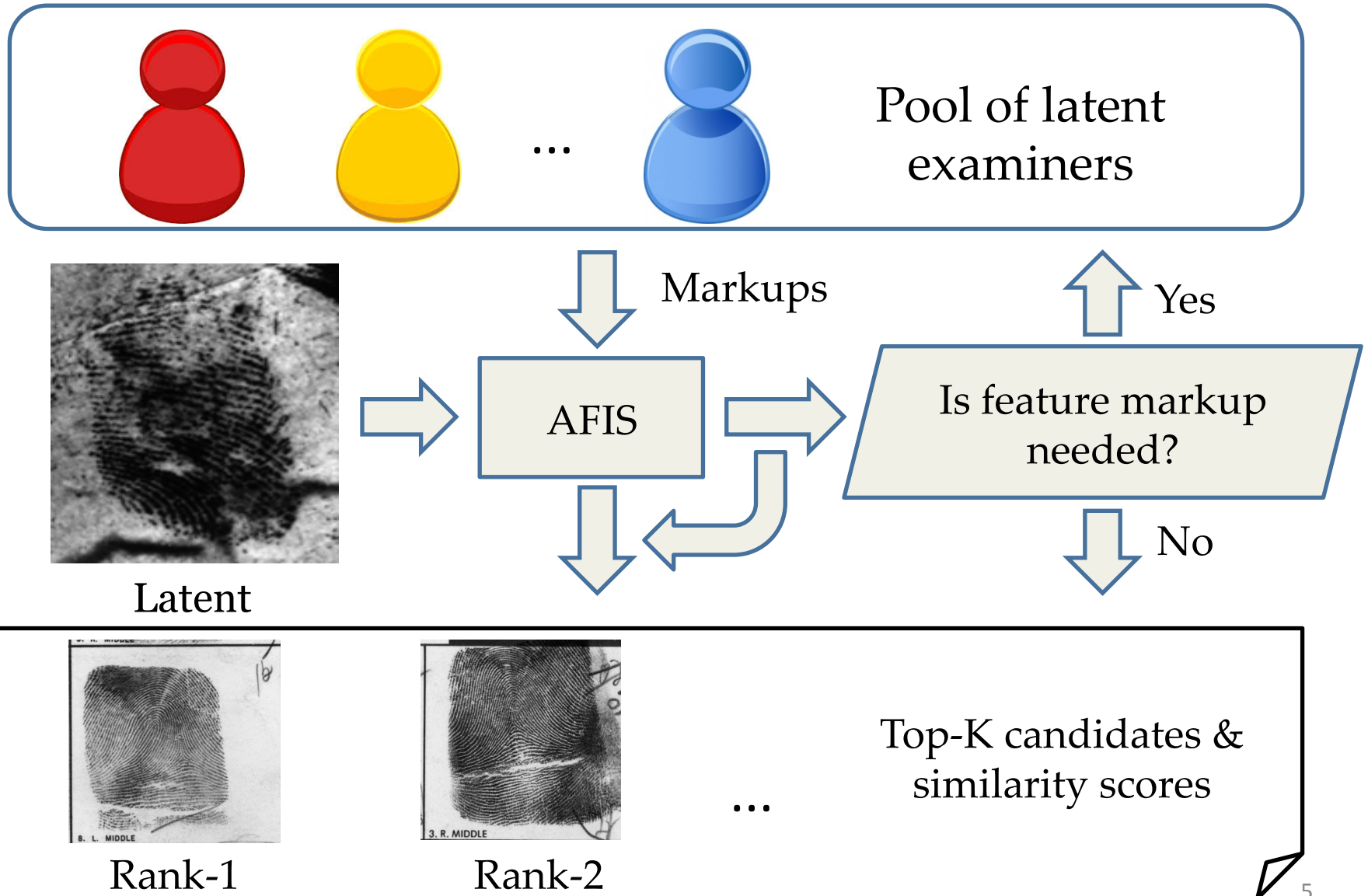

Markup 1: Hit at **rank-1**

Markup 2: Hit at **rank-129**

Approach

- Use collective wisdom of multiple examiners
- Expert crowdsourcing [3]: use a team of latent examiners for markup as needed


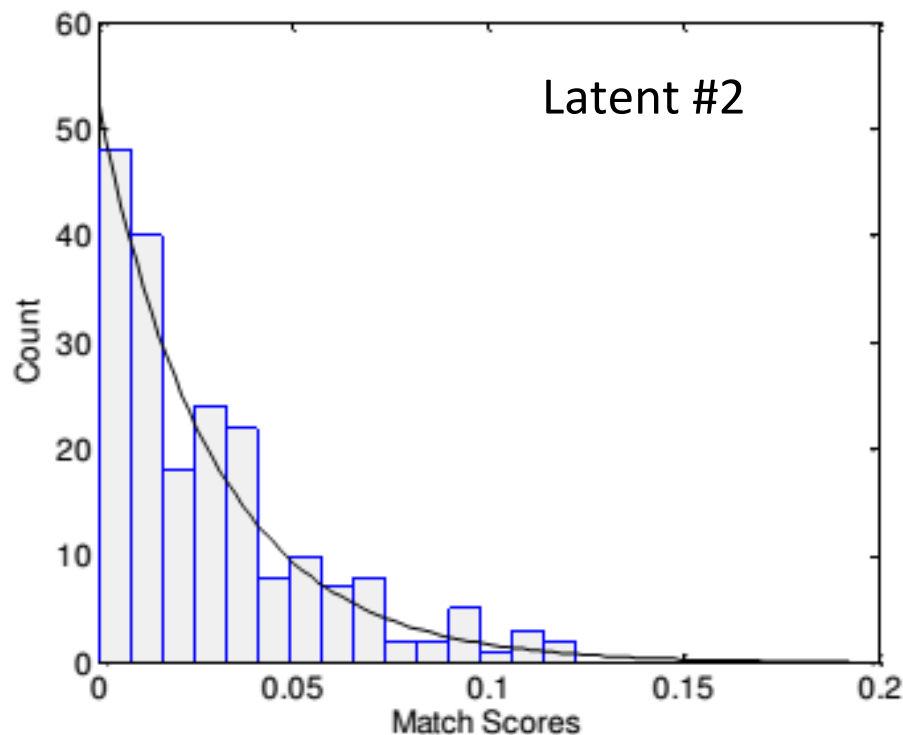[3] D. Retelny, S. Robaszkiewicz, A. To, W. Lasecki, J. Patel, N. Rahmati, T. Doshi, M. Valentine, and M. S. Bernstein. Expert crowdsourcing with flash teams. In ACM Symposium on UIST, 2014.

Expert Crowdsourcing Framework

Pool of latent examiners

Markups

Latent

AFIS

Is feature markup needed?

Yes

No

Rank-1

Rank-2

...

Top-K candidates & similarity scores

When to Crowdsource?

Histogram of top-K comparison scores between latent query and reference images
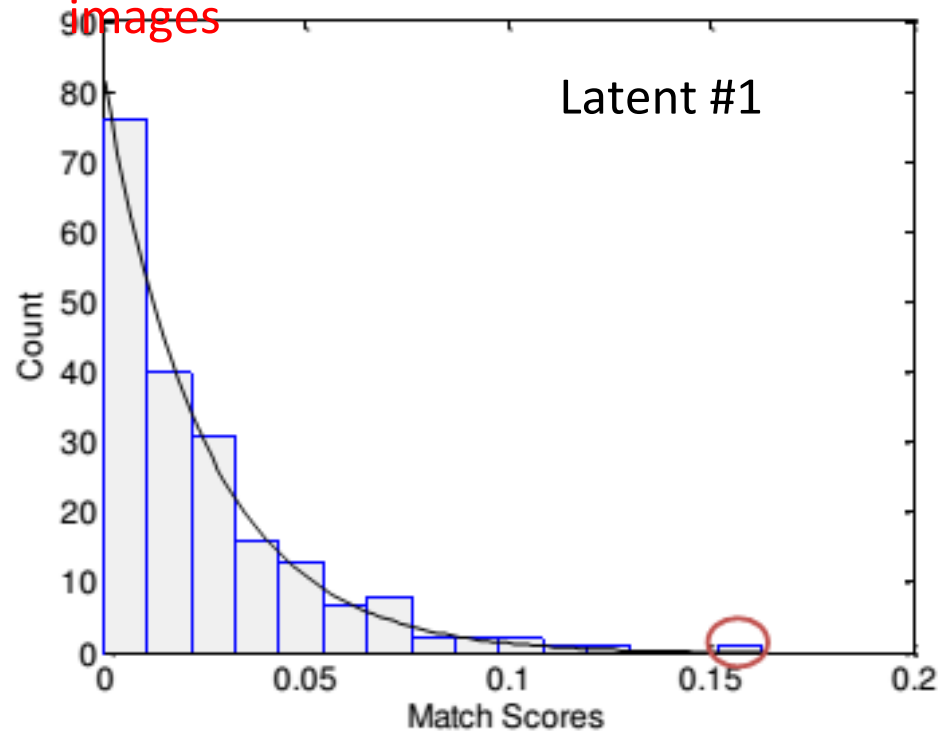
Latent #1

Latent #2

**Upper outlier detected
=> Lights-out AFIS adequate**

**No upper outlier detected
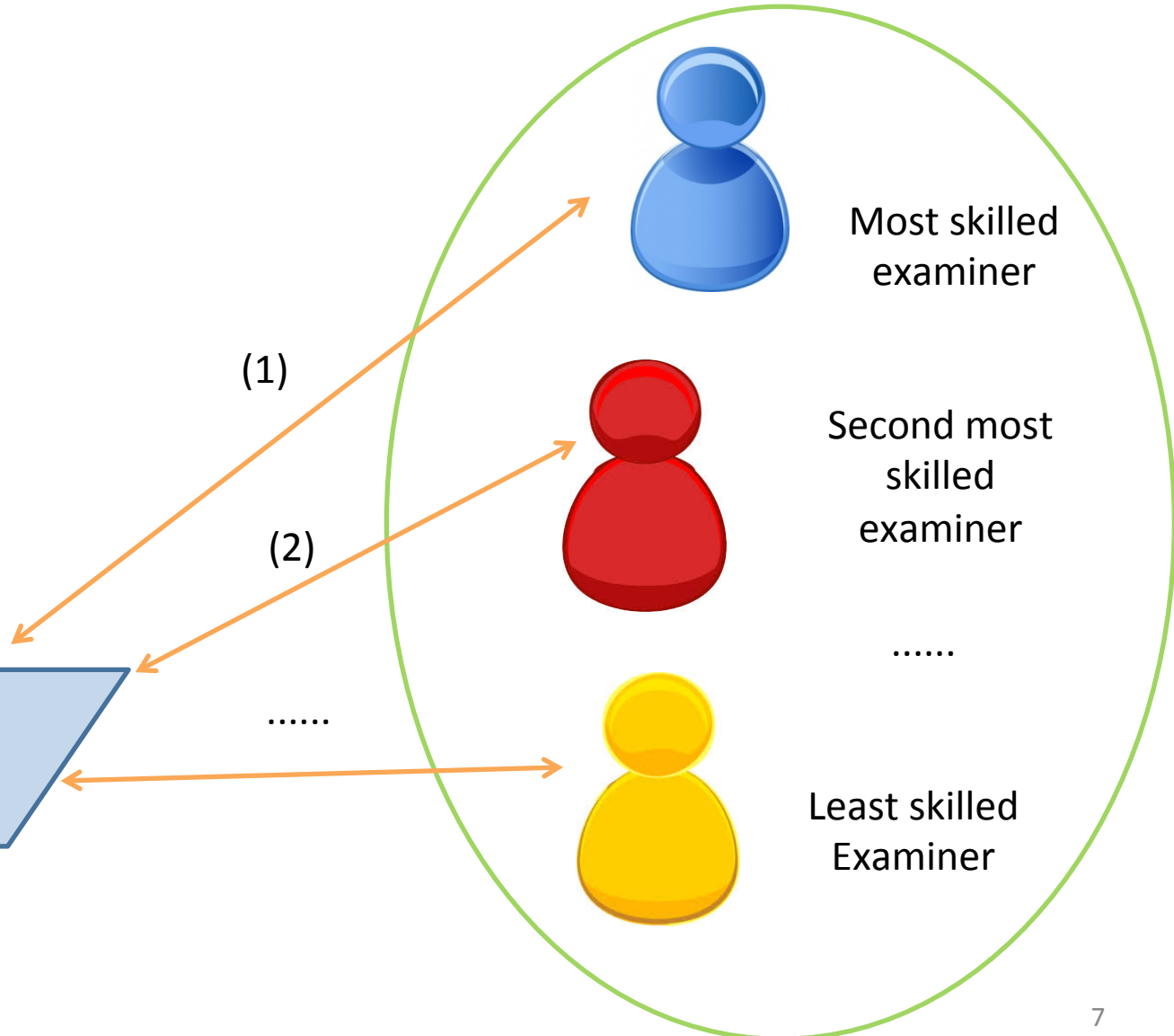=> Obtain examiner markups**

[3] S. S. Arora, E. Liu, K. Cao and A. K. Jain, "Latent Fingerprint Matching: Performance Gain via Feedback from Exemplar Prints", IEEE TPAMI, 2014.

How Many Experts are Enough?

Latent

AFIS

Decide whether additional markup is needed

Top-K candidates and scores

(1)

(2)

......

Most skilled examiner

Second most skilled examiner

......

Least skilled Examiner

Experiments

- Latent Databases

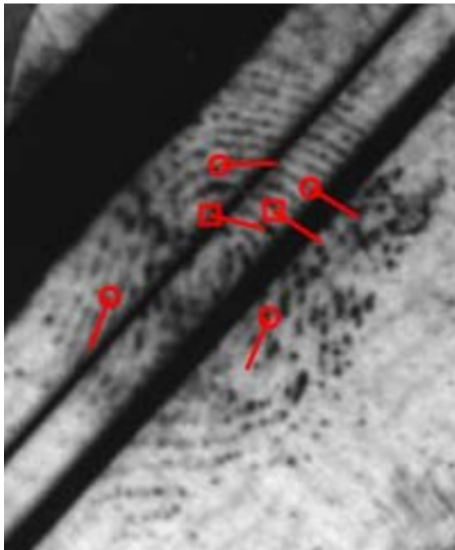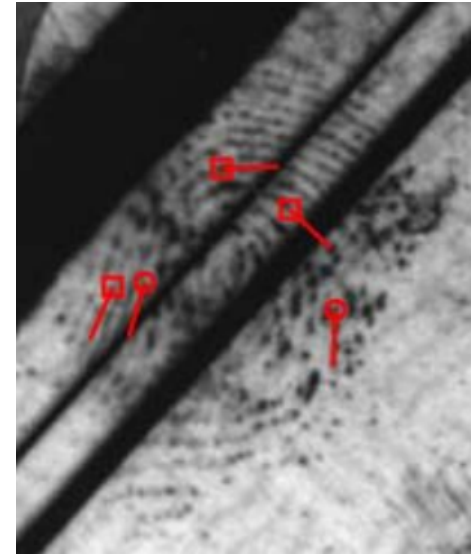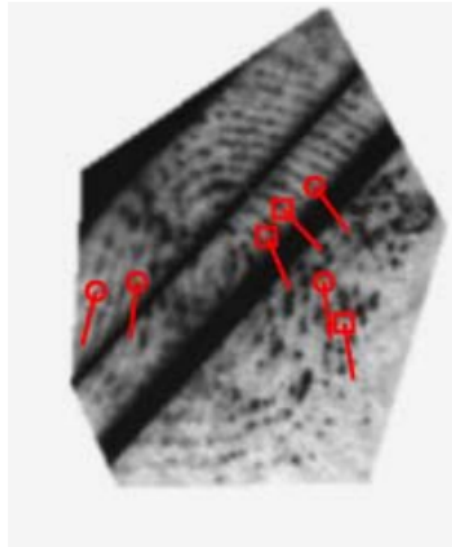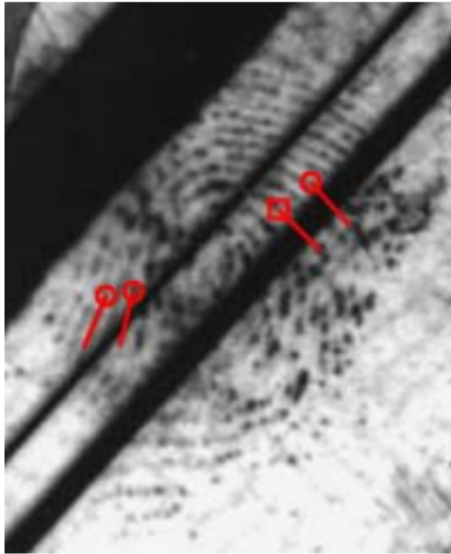| Database	#Latents	Resolution	Latent type	#Examiner Markups
NIST SD27	258	500	operational	6
ELFT EFS	255	1000	operational	2
RS&A	200	1000	collected in lab	1

- Reference Database
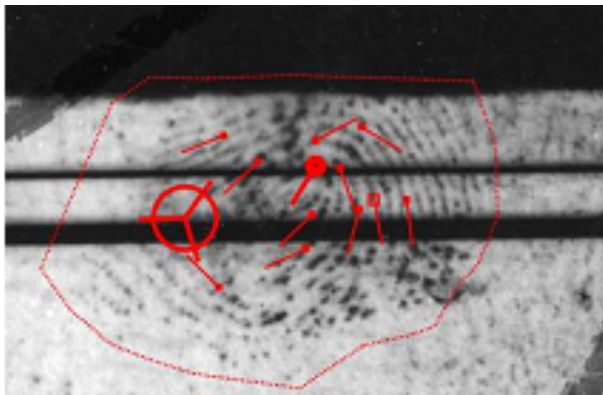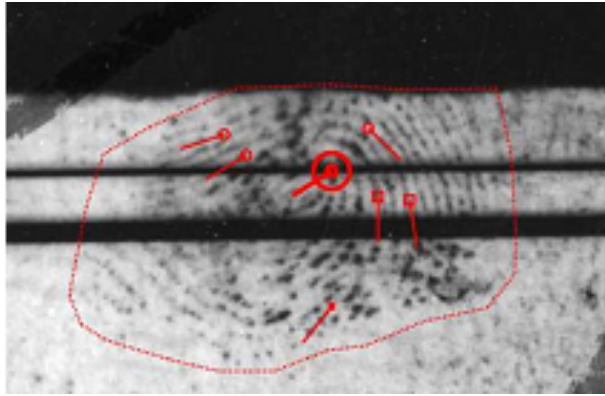 - 250K rolled prints (true mates, MSP, NIST)

- Latent AFIS
  - Top performing system in NIST ELFT-EFS 2
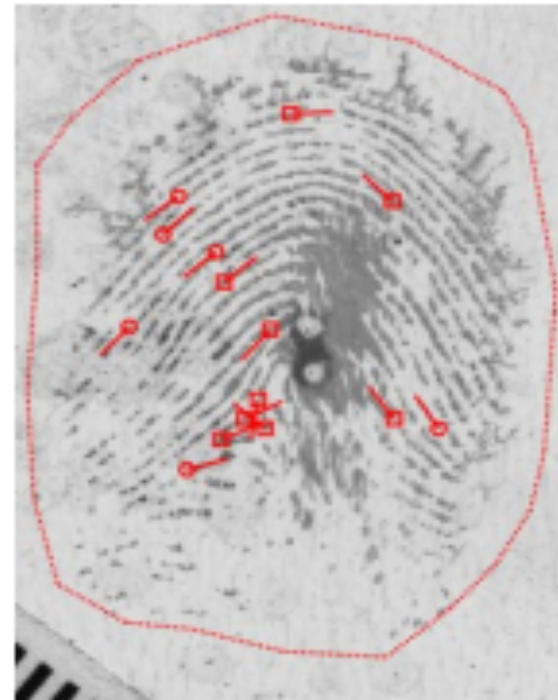
Sample Markups: NIST SD27
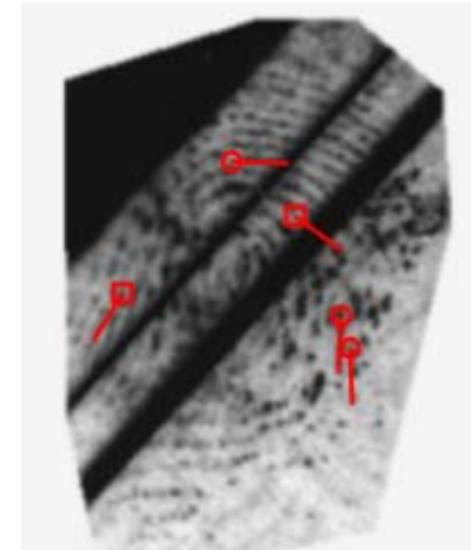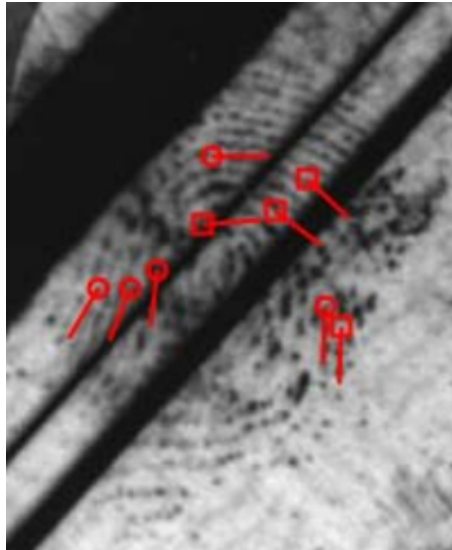
Markups by 6 examiners for a latent in NIST SD27
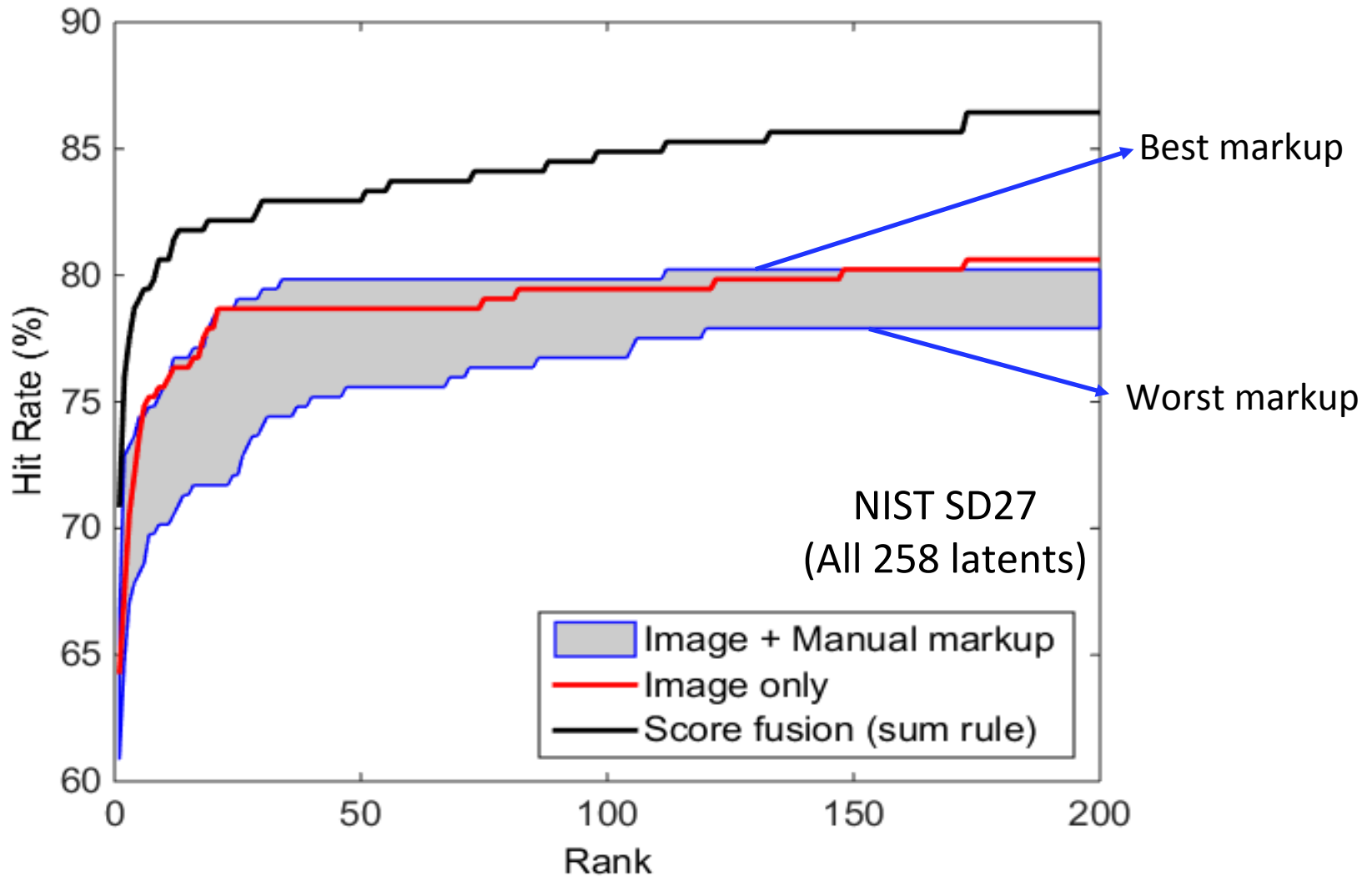
Sample Markups: ELFT EFS & RS&A
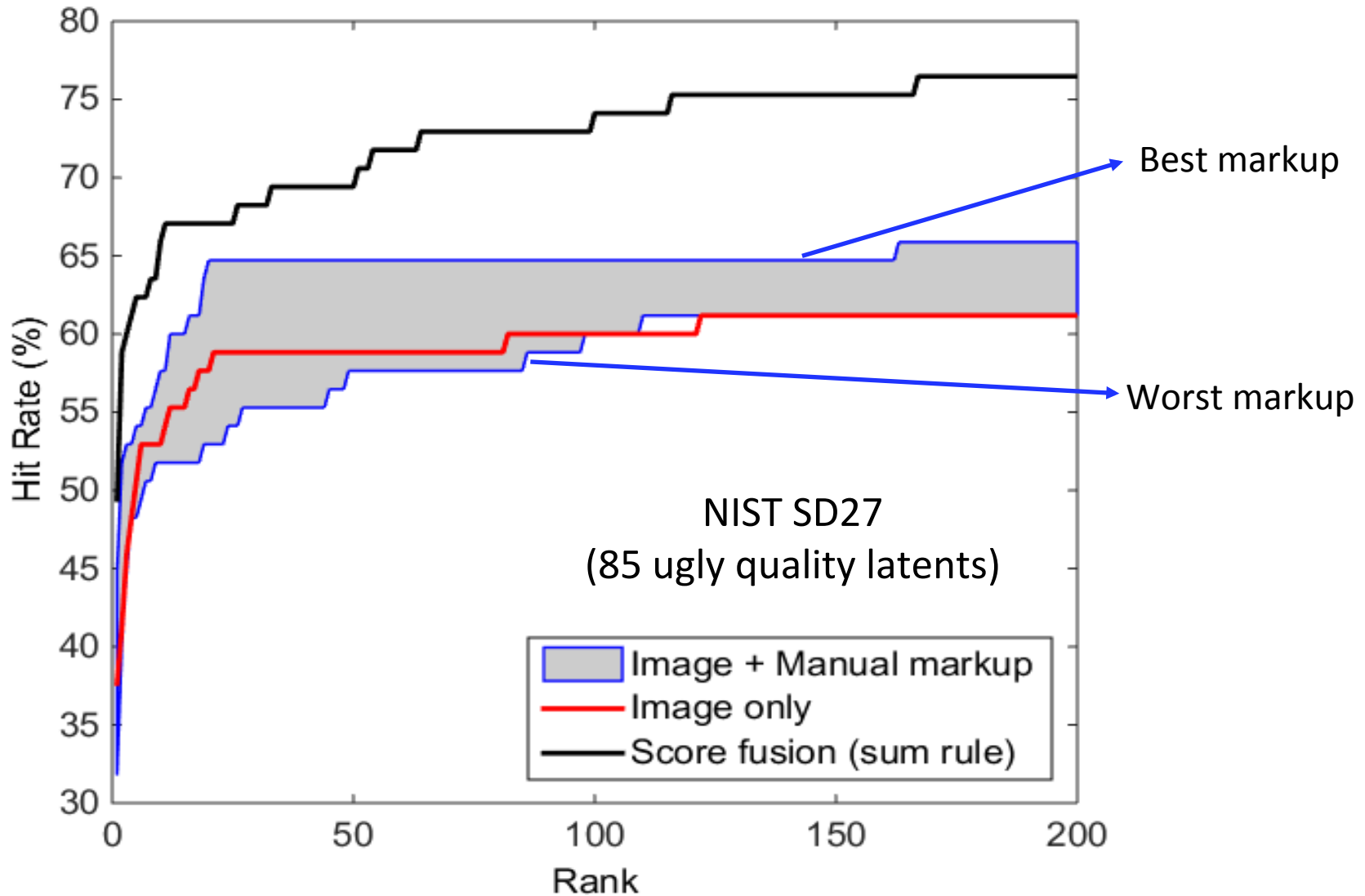

Markups by two examiners
for a latent in ELFT EFS

Only a single markup
available for latents in RS&A

Performance of Crowdsourcing

Rank-1 hit rate improves by ~7.75%

Performance of Crowdsourcing

NIST SD27
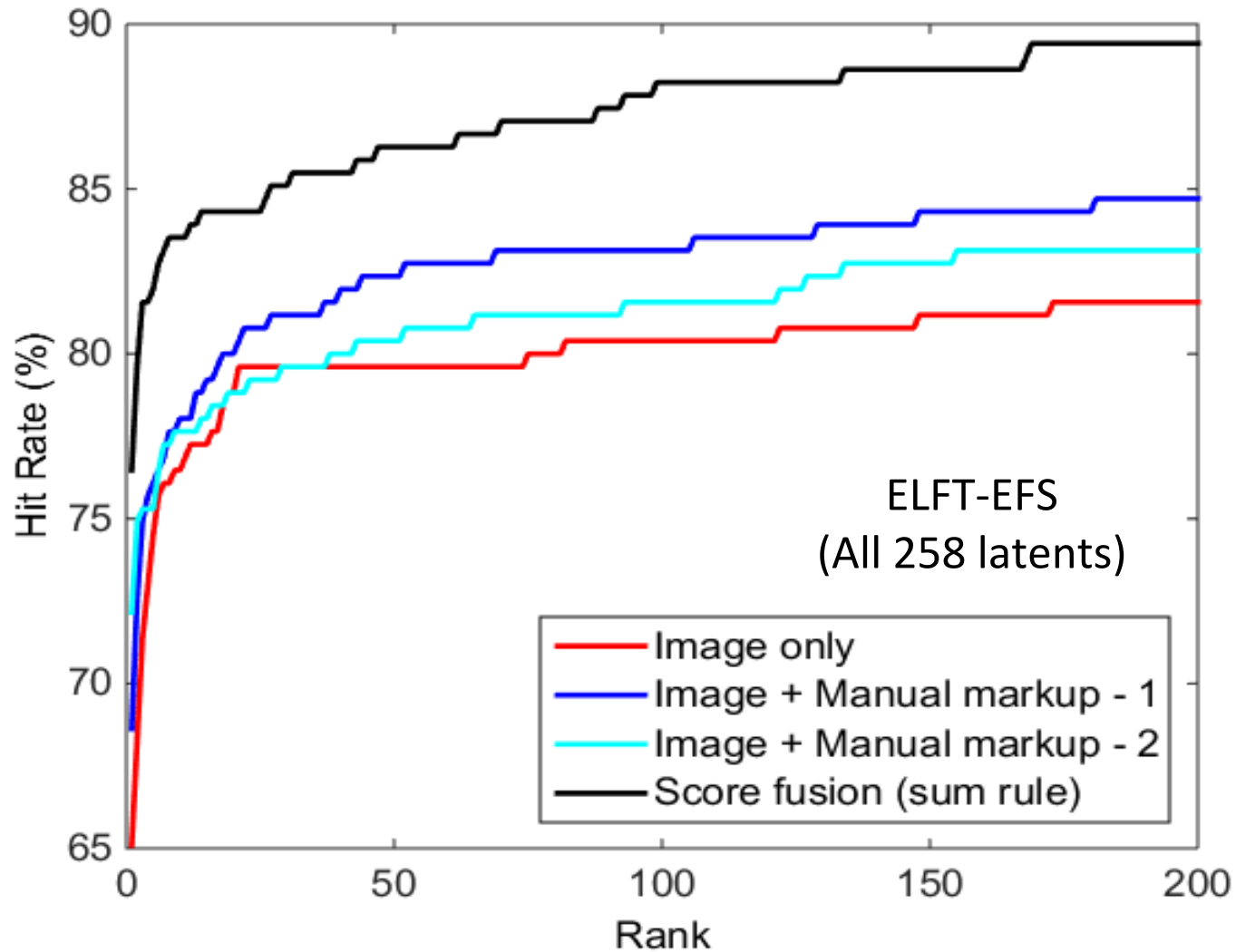(85 ugly quality latents)

Best markup

Worst markup

Image + Manual markup
Image only
Score fusion (sum rule)

Hit Rate (%)

Rank

Rank-1 hit rate improves by ~12%

Performance of Crowdsourcing

- Different combinations of examiners

Combination	Rank-1	Rank-50	Rank-100
One examiner	63.11	77.13	78.23
Two examiners	68.04	80.88	81.96
Three examiners	69.42	82.15	83.29
Four examiners	**70.00**	**82.71**	**83.98**
Five examiners	70.80	83.14	84.56
All six examiners	70.93	82.95	84.88

Hit rates using different subsets of latent examiners
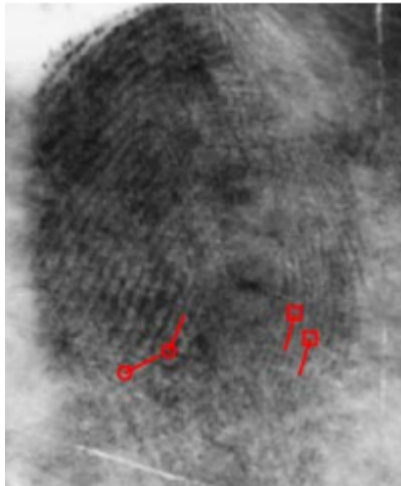
Performance of Crowdsourcing

ELFT-EFS
(All 258 latents)

Legend:
- Image only
- Image + Manual markup - 1
- Image + Manual markup - 2
- Score fusion (sum rule)

Rank-1 accuracy improves by ~11.5%

Performance of Crowdsourcing

RS&A
(All 200 latents)

Legend:
- Image only
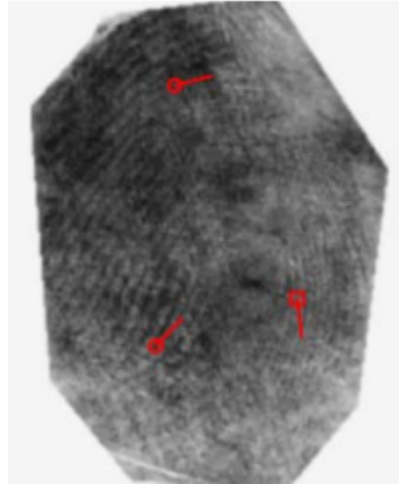- Image + Manual markup
- Score fusion (sum rule)
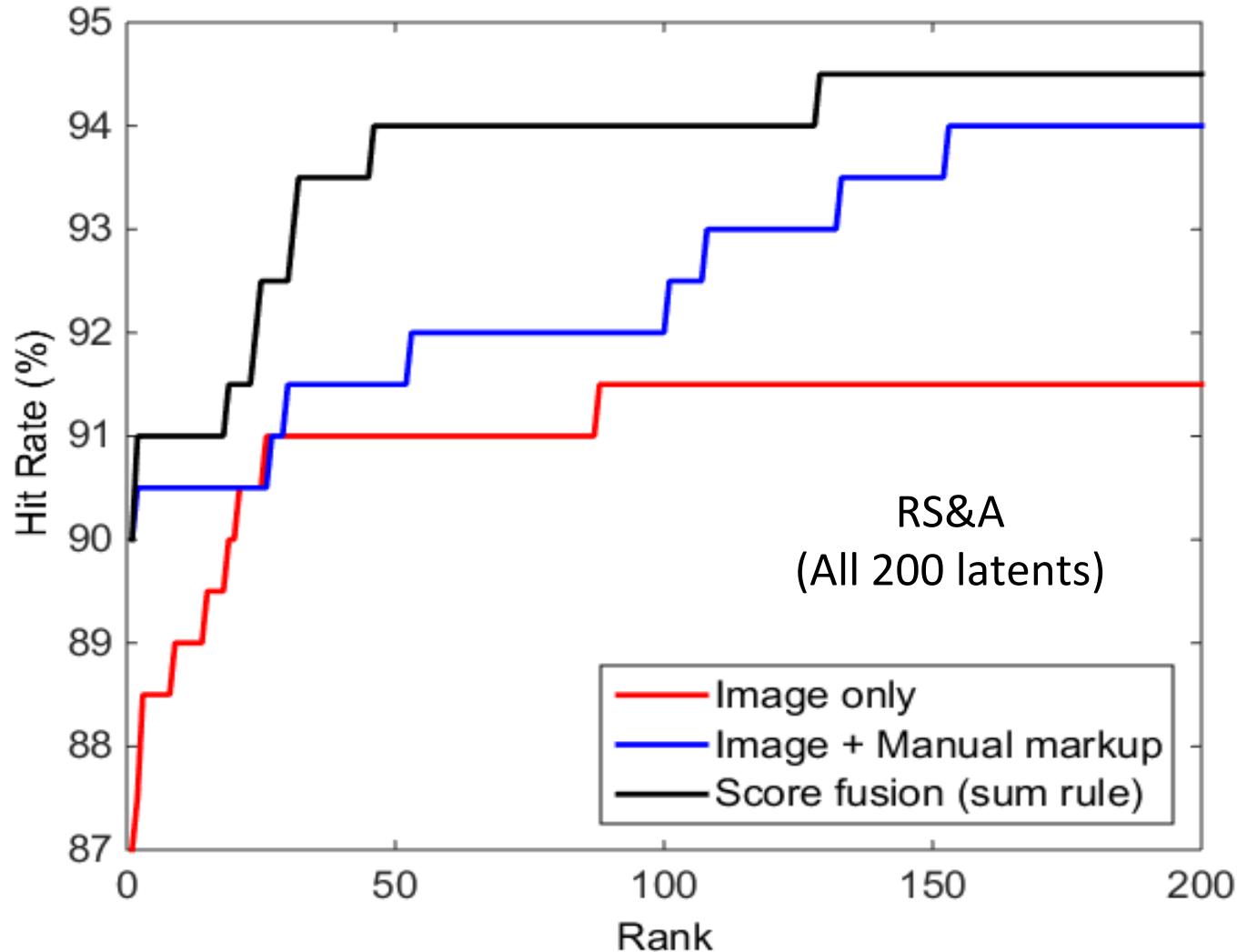
Rank-1 accuracy improves by ~2.5%

Performance Improvement Example

Markup 1
(Rank 80)

Markup 2
(Failed to match)

Markup 3
(Rank 45)
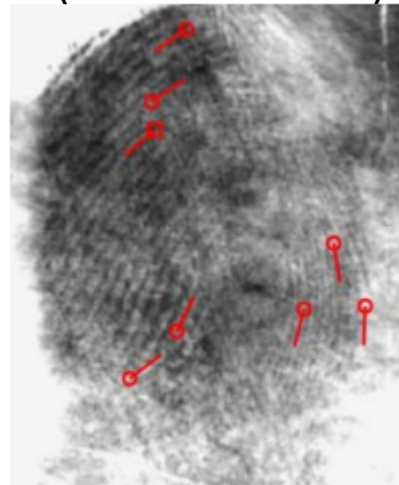

Markup 4
(Rank 7)

Markup 5
(Rank 57)

Markup 6
(Rank 12,971)

Lights-out:
Failed to match

Fusion rank: 2

NIST SD27
(Latent 236)

16
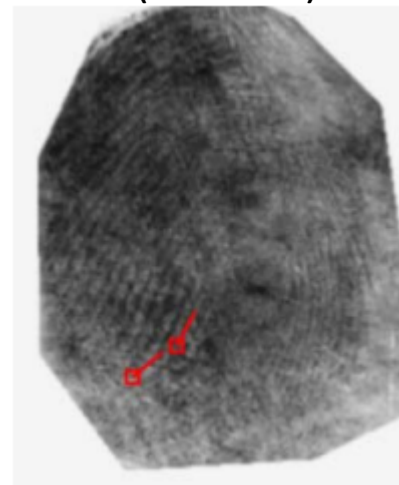
Performance Improvement Example

- ## NIST SD27 (Latent 83)
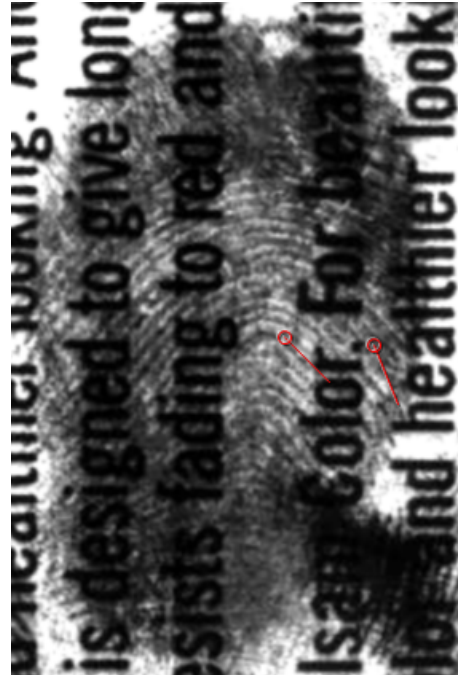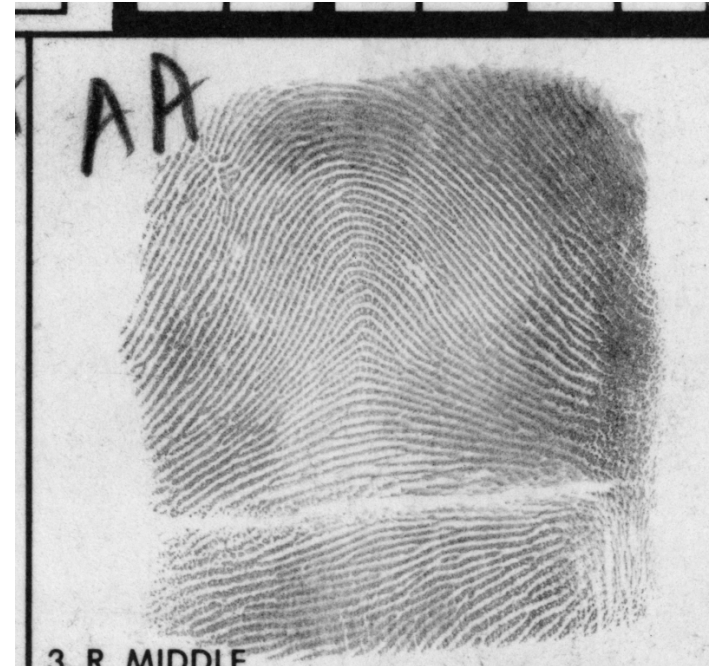
| Image only | Image + Markup-E1 | Mated Exemplar |

	Image only	**Image + Markup-E1**	**Fusion (All 6)**
Rank	Failed to match	Failed to match	2 (score: 226)

Performance Decrease Example

- NIST SD27 (Latent 206)
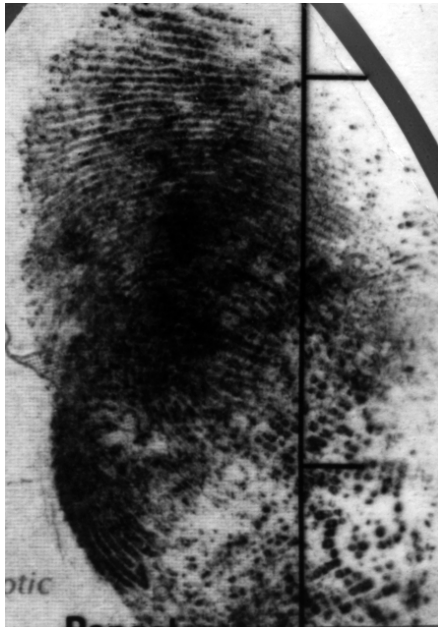
Image only

Mated Exemplar

	Image only	**Fusion (All 6)**
Rank	82 (score: 97)	116 (score: 411)

Greedy Crowdsourcing

Shown in red are the number of latents given to the next best examiner for feature markup
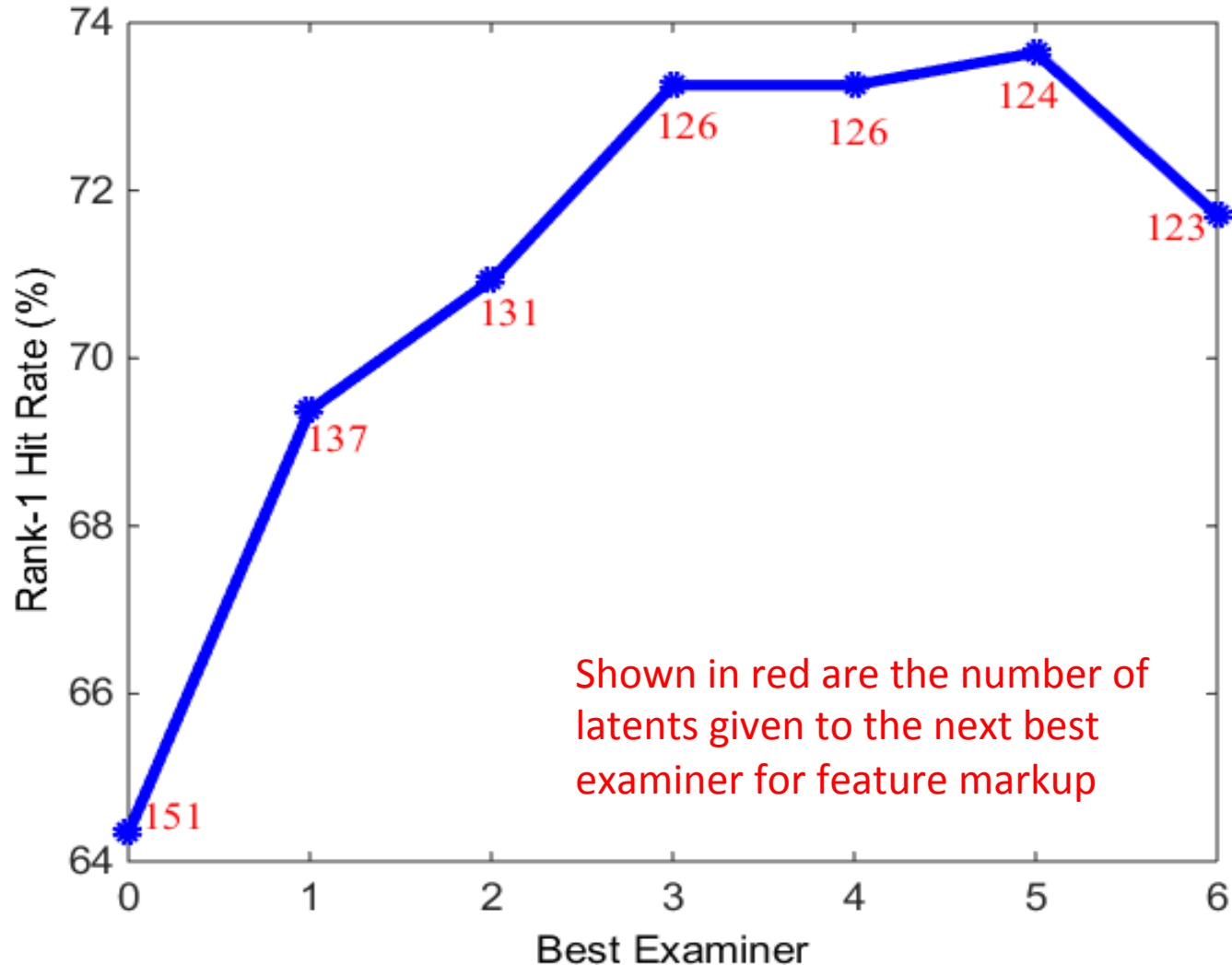
Performance improvement saturates after 3 best examiners for NIST SD27

Conclusions and Next Steps

- Wisdom of multiple latent experts is effective for latent fingerprint identification

- Performance of a latent AFIS is significantly improved (~7.75 % on NIST SD27)

- Next steps:
  - Evaluate open-set identification performance
  - Incorporate latent quality
  - Explore meta-algorithms such as boosting and bagging to improve AFIS performance