NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Quantifying the weight of friction ridge evidence Score-based Likelihood ratio for fingerprints

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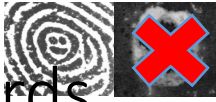
Image Group, NIST

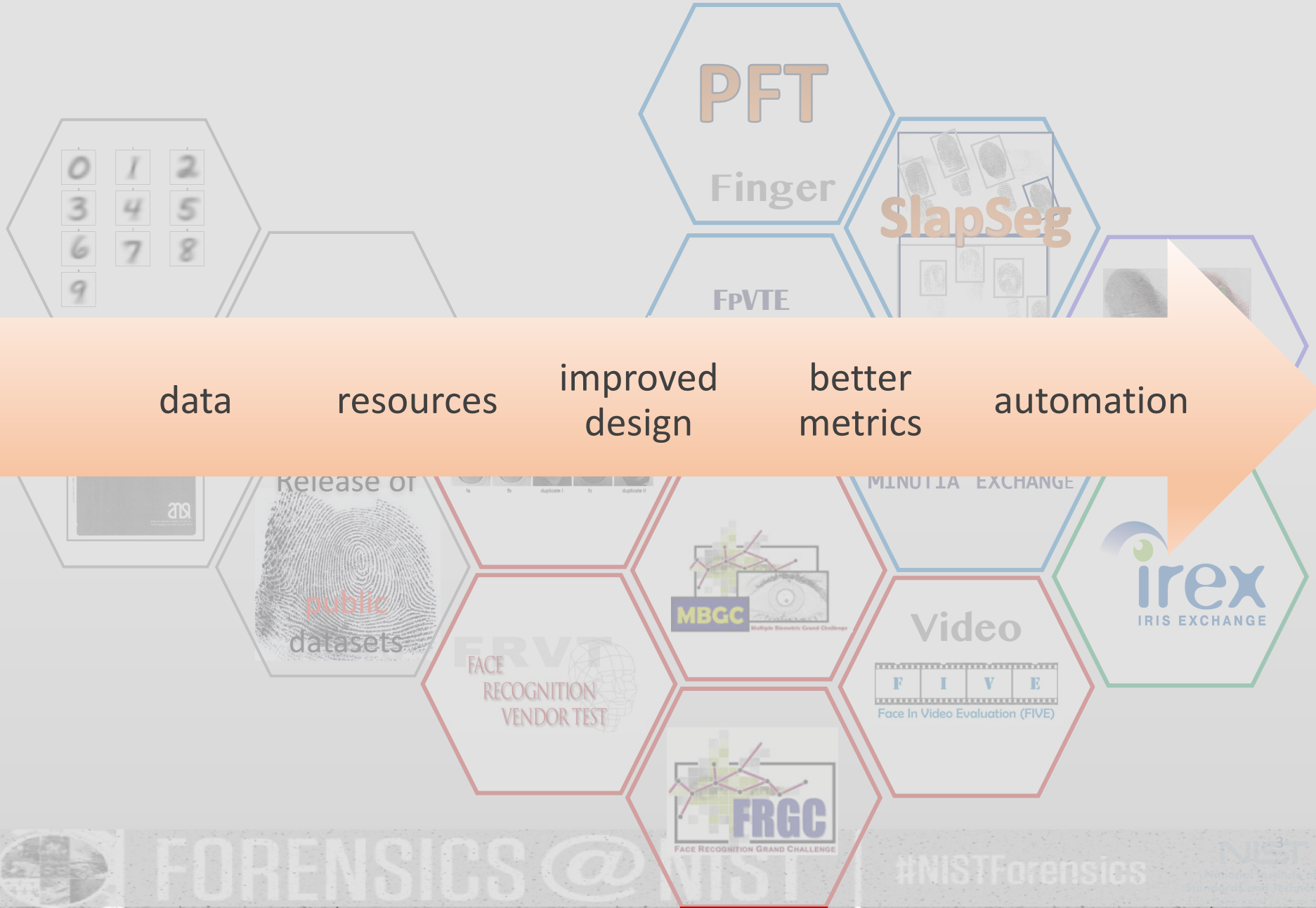
November 8, 2016

outline

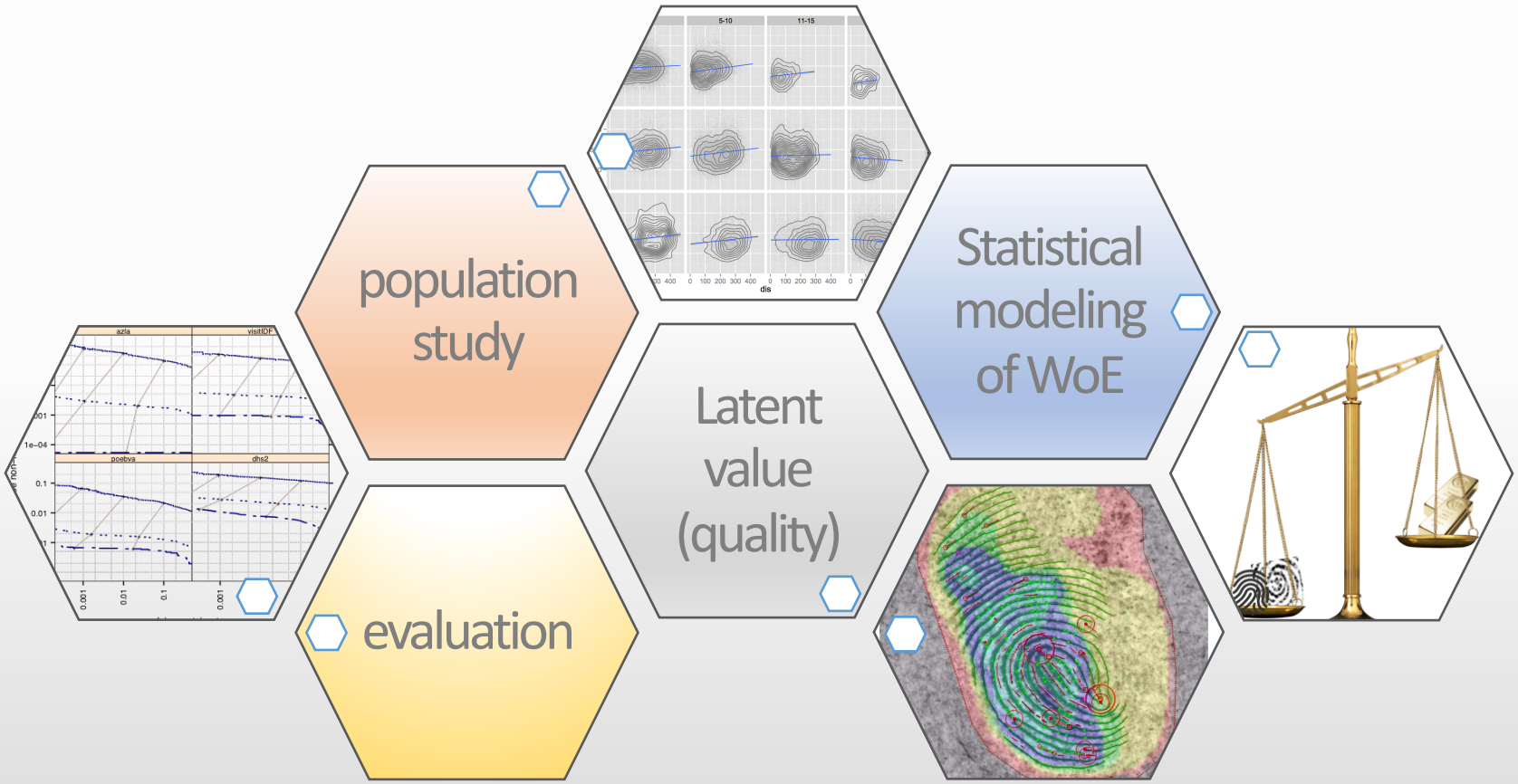
- Who we are
- Friction ridge research area
- ROC curves in Forensics
  - Components in likelihood ratios
  - Score-based likelihood ratio
  - ROC curve vs. likelihood ratio
- Latent value determination
- Upcoming events
- conclusion

Who we are: biometrics research, evaluation and Standards





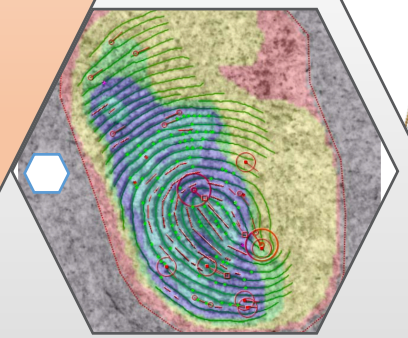
Friction Ridge Researh area



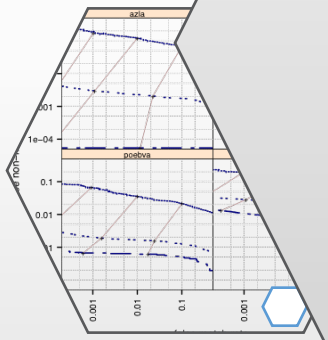
Friction Ridge Research area

Population Study
develop explicit probability models for the measurements obtained from latent prints, and to use these models to draw inferences about the probative value (or weight of evidence) of a given crime-scene sample and the sample from a person of interest.

Statistical
odeling
f WoE



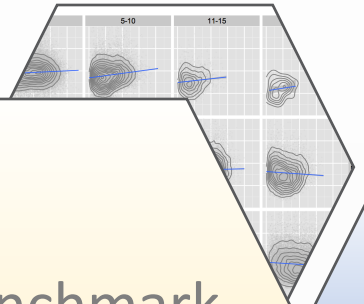
Friction Ridge Research area



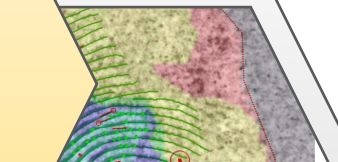
Latent value (quality)

Development of fully automated method to assign objective quantitative quality values to latent fingerprints.

Friction Ridge Research area



Statistical modeling of WoE



Evaluations

Latent Challenge to benchmark current core algorithm capabilities and push towards future technologies and examine their feasibility.

Collaborative Exercises

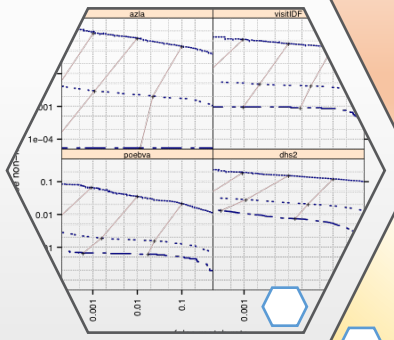
Understand current state of quantifying and interpreting WoE.

Friction Ridge Researc

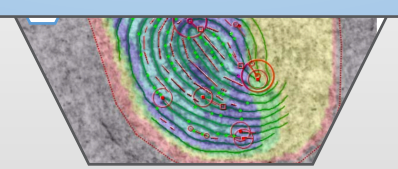
Statistical modeling of WoE

Improve the measurement and quantification of the weight of evidence on fingerprint using measurement from image (feature-based) or comparison scores (score-based).

popula
study



evaluation



What is WoE
How to quantify WoE

- Glass: Parker (1966), Evett (1977), Lindley (1977)
- Hair or fiber: Peabody et al. (1983) and Aitken (1986); Evett et al. (1987)
- DNA: Berry (1991), Berry et al. (1992), Butler (2005), Weir (2007)
- Handwriting: Bozza et al. (2008), Saunders et al. (2011), Hepler et al. (2012)
- Fingerprint: Stoney (1991), Neumann et al. (2011)

Likelihood ratio

$$LR = \frac{Pr(X, Y|H_p, I)}{Pr(X, Y|H_d, I)}$$

- X evidence measurements of unknown source
- Y evidence measurements of known source
- Prosecution hypothesis (H_p): X and Y are from the same source
  - X and Y are correlated.
  - The variation of X and Y is from within source.
- Defense hypothesis (H_d): X and Y are from different sources
  - X and Y are independent.
  - The variation of X and Y is from between sources.

Bayes Factor

- LR is also Bayes factor, since the posterior odds is given by

$$\frac{\Pr(H_p|X,Y)}{\Pr(H_d|X,Y)} = \text{LR x } \frac{\Pr(H_p)}{\Pr(H_d)}$$

- Parametric assumption in Lindley (1977)
  - $X_i \sim N(\theta_1, \sigma^2), i = 1, \cdots, m$ and $Y_j \sim N(\theta_2, \sigma^2), j = 1, \ldots, n$
  - $\theta_\ell \sim N(\mu, \tau^2)$

$$LR = \frac{f(X_1, \ldots, X_m, Y_1, \ldots, Y_n|H_p)}{f(X_1, \ldots, X_m, Y_1, \ldots, Y_n|H_d)}$$

$$= \frac{\int f(\bar{X}_m, \bar{Y}_n|\theta) f(\theta) d\theta}{\int f(\bar{X}_m|\theta_1) f(\theta_1) d\theta_1 \int f(\bar{Y}_n|\theta_2) f(\theta_2) d\theta_2}$$

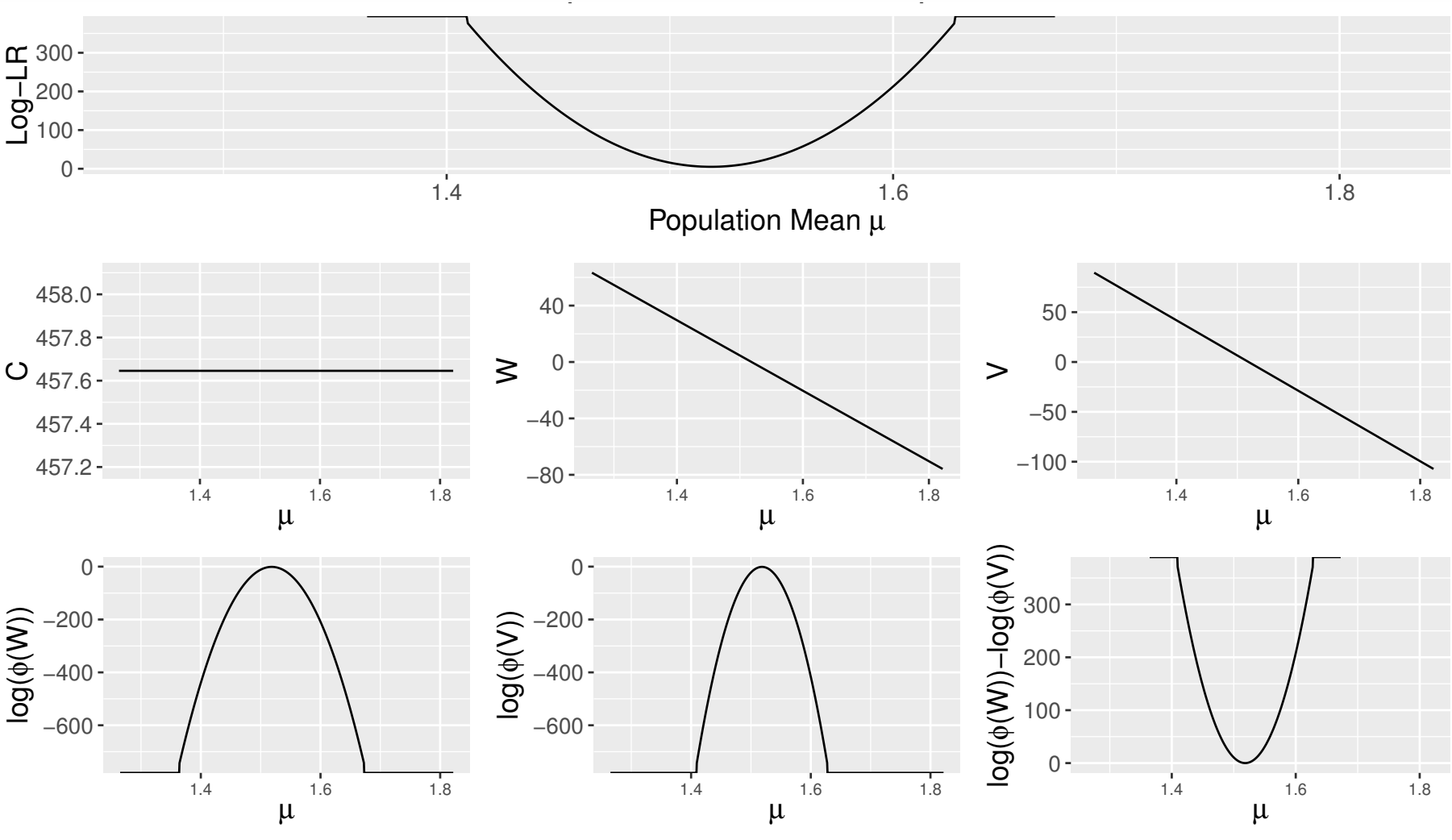
Components of LR

- Assuming between-source variation much larger than within-source variation
- $logLR = logC + log\phi(Z_{m,n}) + log\phi(W_{m,n}) - log\phi(V_{m,n})$

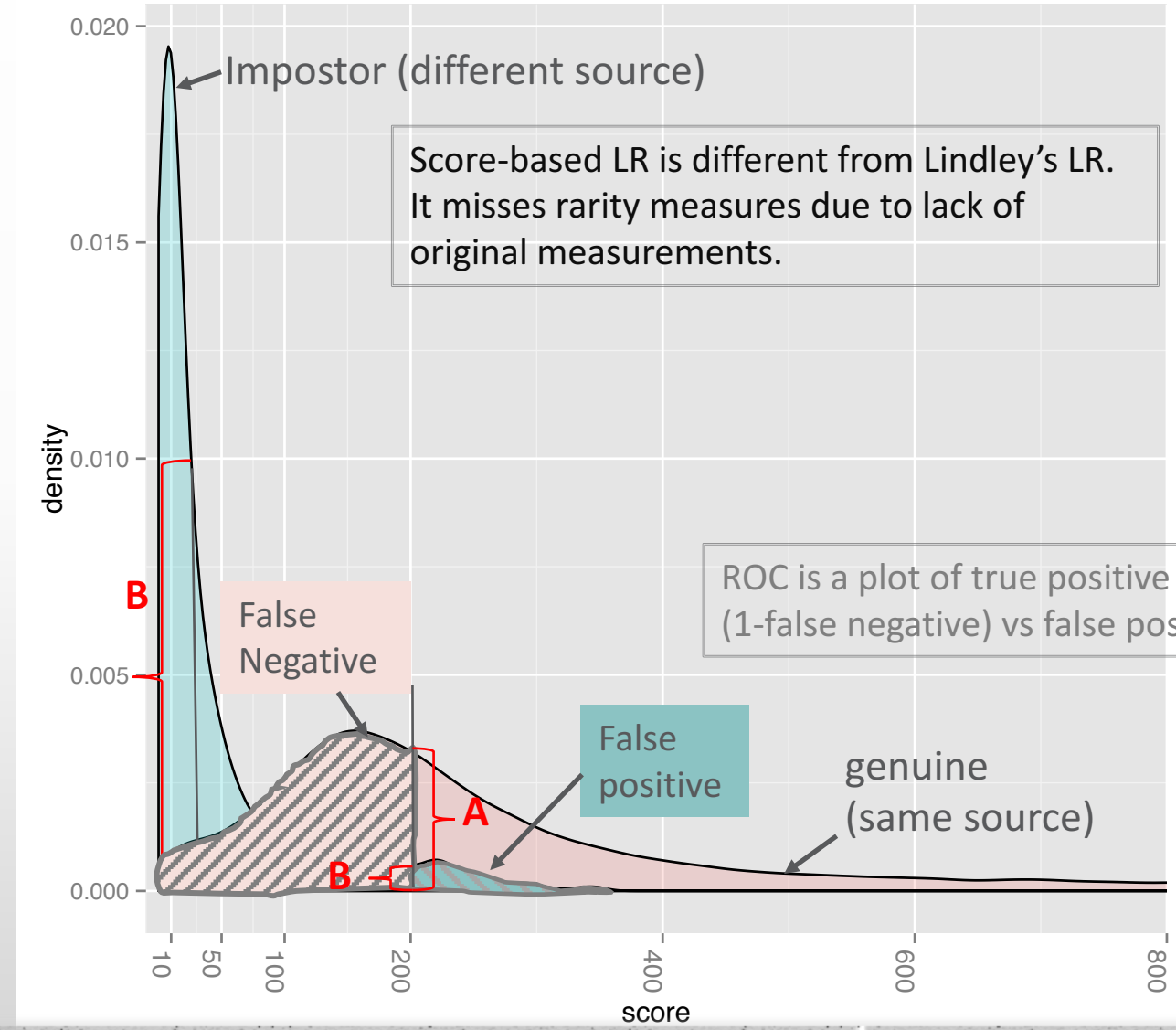
constant similarity rarity

- The estimate for the logarithm is obtained by using realized values from the evidence measurements.
  - Constant term: $C = \sqrt{2\pi}\,\tau/(\sigma\sqrt{1/m + 1/n})$
  - Difference term: $Z_{m,n} = (\bar{X}_m - \bar{Y}_n)\,/(\sigma\sqrt{1/m + 1/n})$
  - Rarity terms: $W_{m,n} = (Y^*_{m,n} - \mu)\,/\tau$ and $V_{m,n} = \sqrt{2}(Y'_{m,n} - \mu)\,/\tau$
- $logLR$ is a function of sample means, sample sizes (m, n), within source and between source variations, and *population mean* μ.

LR vs. Population Mean μ



Score-based LR = $\frac{f_p(S_{X,Y})}{f_d(S_{X,Y})} = \frac{A}{B}$



Score-based LR and ROC

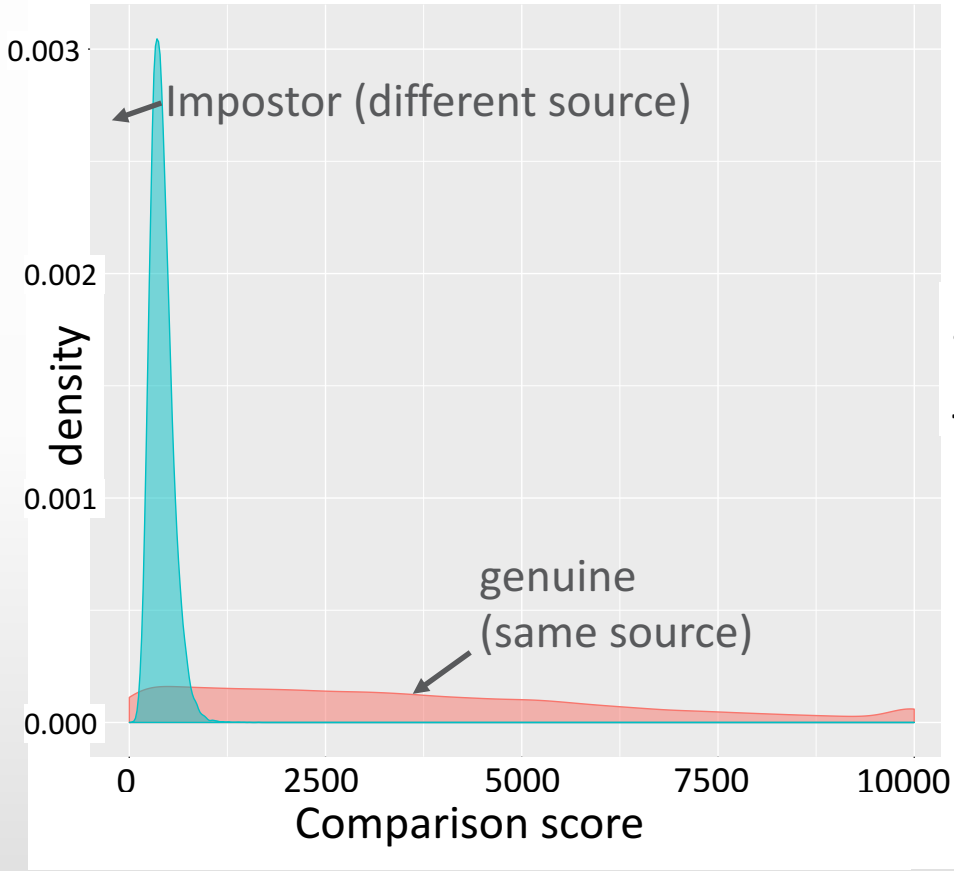
- The first derivative of an ROC curve has been shown to be closely related to likelihood ratio (Choi, 1998)
- Derivative of an ROC curve

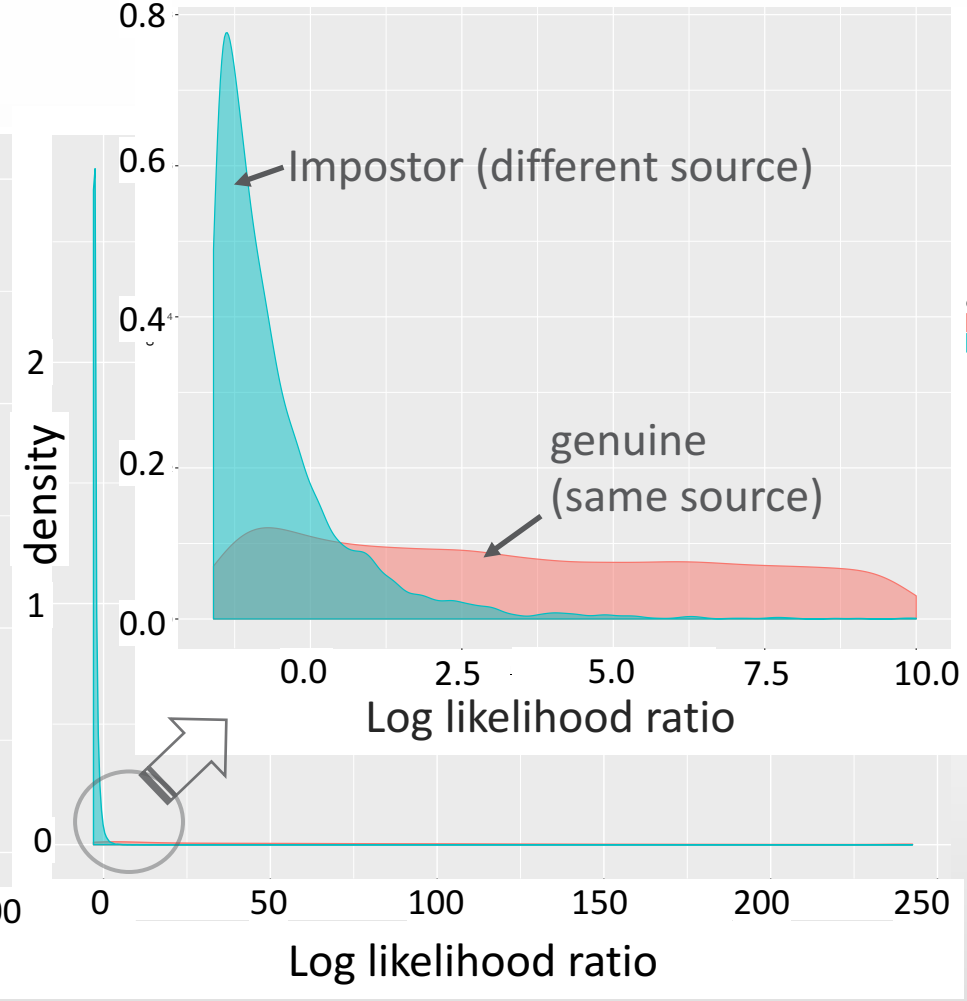
$$R'(u) = \frac{F_p'(F_d^{-1}(1-u))}{F_d'(F_d^{-1}(1-u))}$$

- Let $S_{x,y} = F_d^{-1}(1-u), then\ u = 1 - F_d(S_{x,y})$

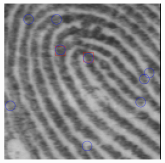
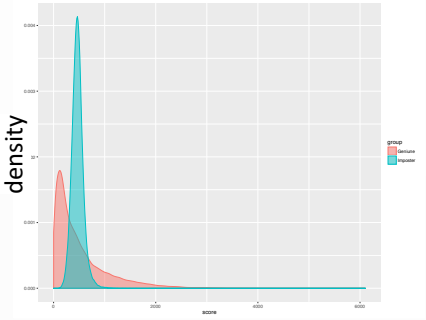
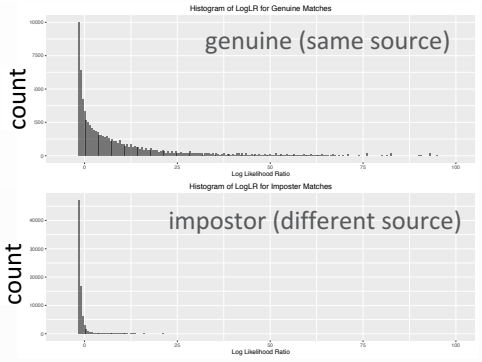
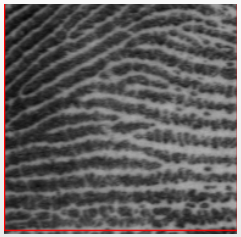
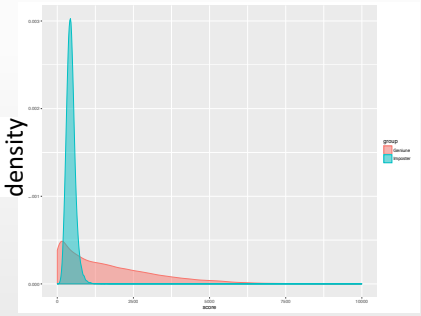
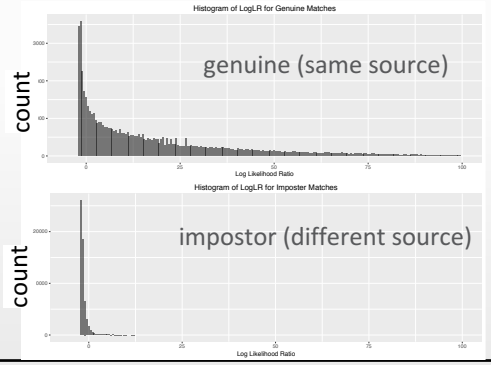
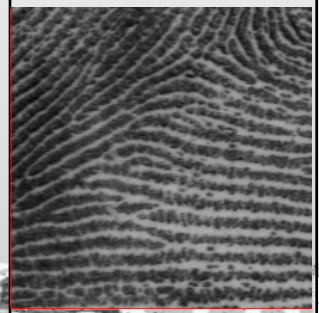
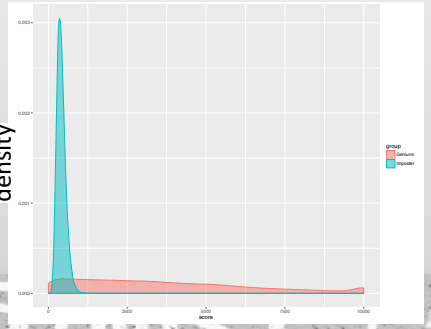
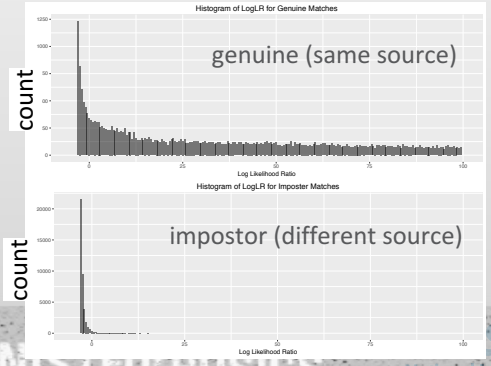
$$SLR(S_{x,y}) = R'(1 - F_d(S_{x,y}))$$

Score-based LR





SLR for `relevant' population?

size	# of minutia	clarity	pattern type	quality	age or gender	Score distribution	Log likelihood
128 x 128 							
192 x 192 							
256 x 256 							

Automated Latent Fingerprint Value Prediction

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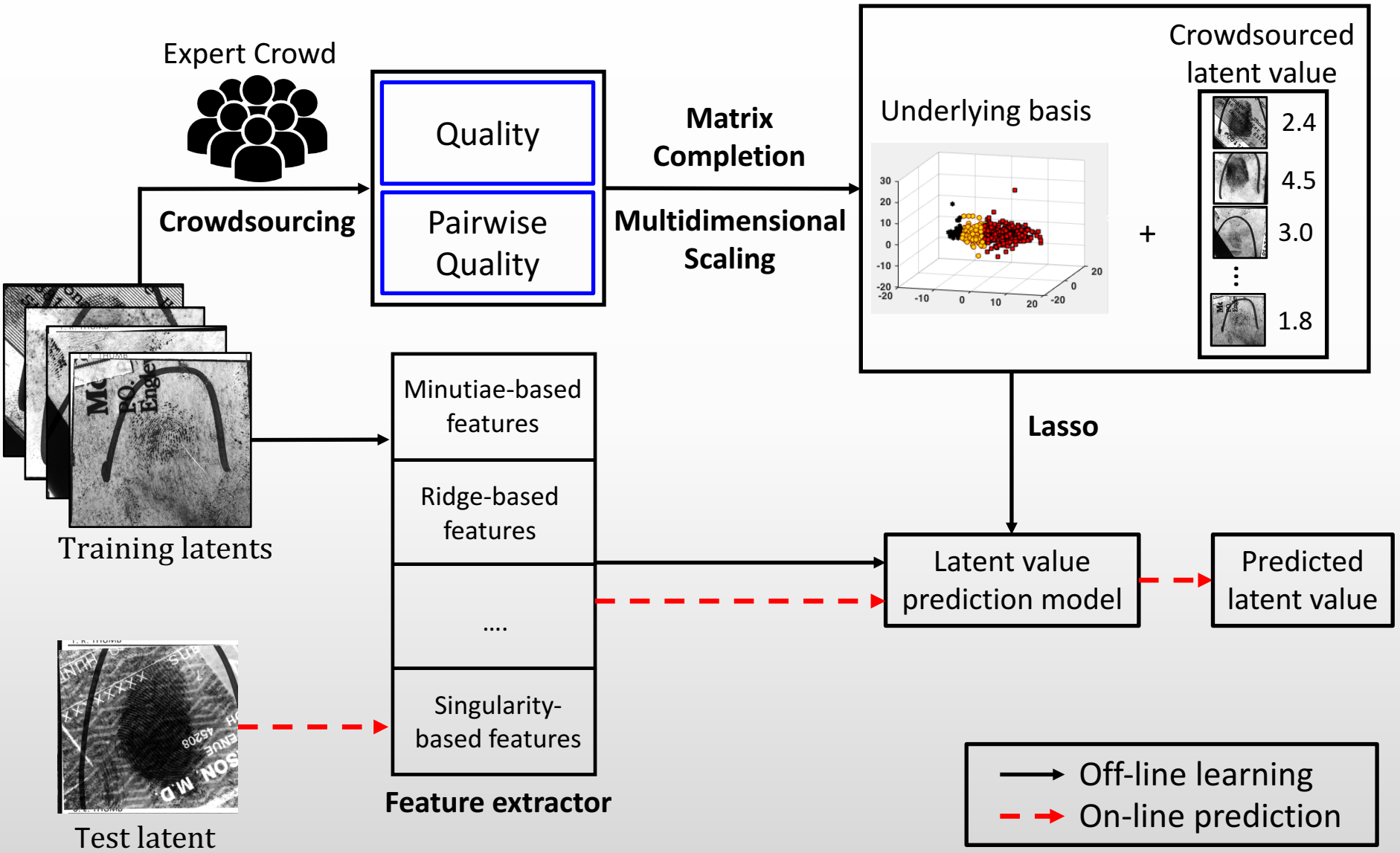
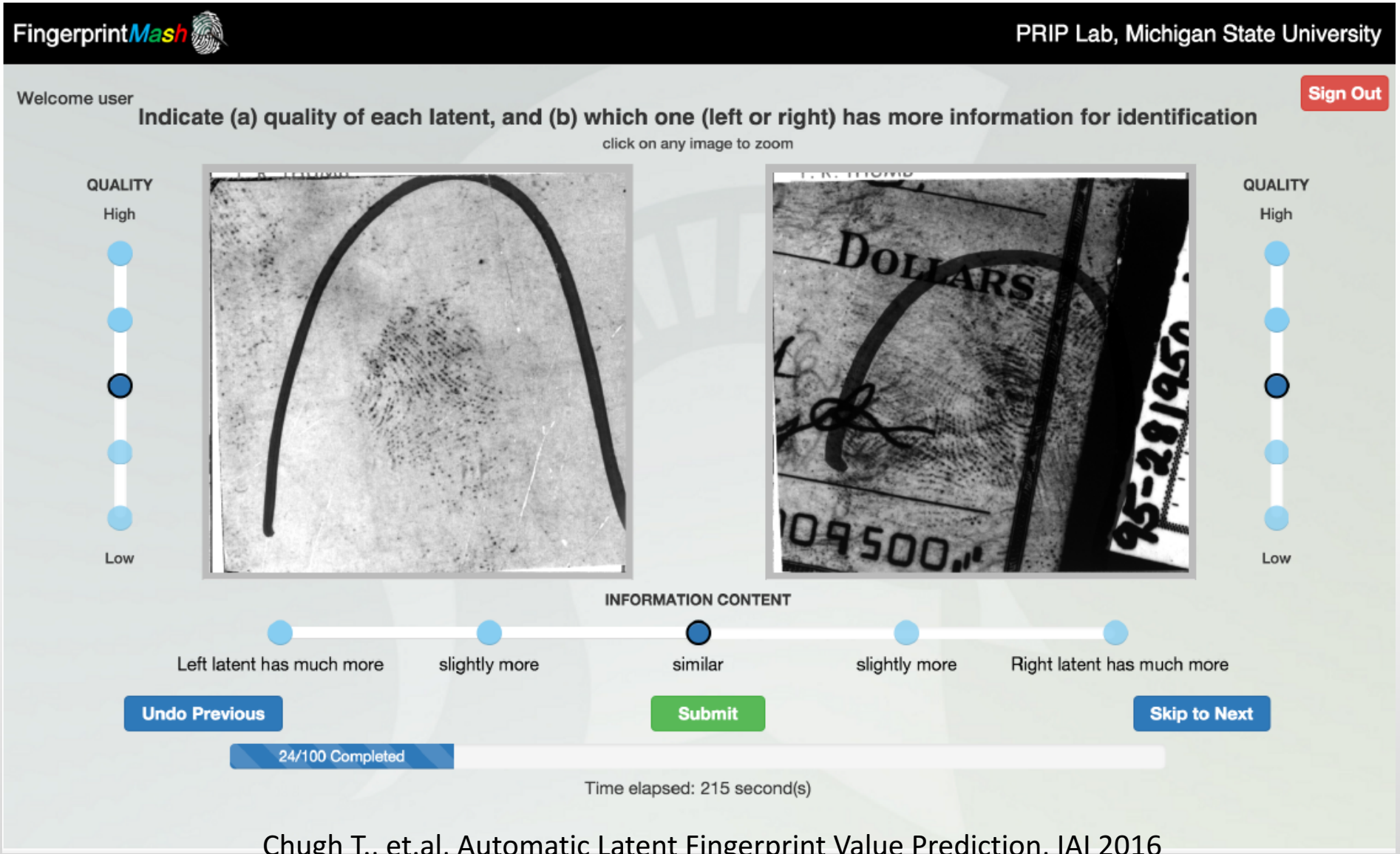
Elham Tabassi [‡] and Anil K. Jain [†]
[†] Michigan State University
[‡] National Institute of Standards and Technology

Proposed method (ML)

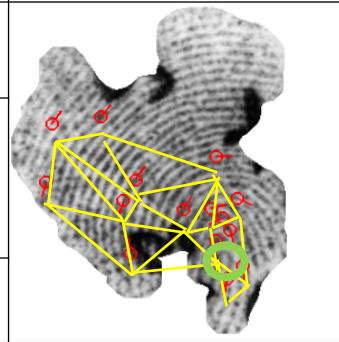
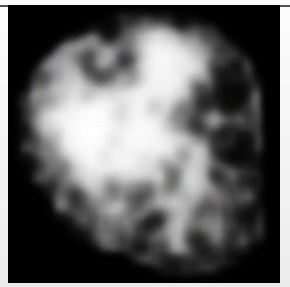
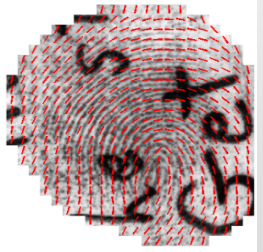


Fingerprint*Mash*



Chugh T., et.al, Automatic Latent Fingerprint Value Prediction, IAI 2016

Features for value assessment

Feature No.	Description	
1	Number of minutiae	
2 - 8	Sum of minutiae reliability with reliability ≥ t, t= 0, 0.1, ..., 0.6	
9	Average area of minutiae Delaunay triangulation	
10	Area of the convex hull of minutiae set	
11 - 17	Sum of ridge quality blocks with quality value ≥ t, t= 0, 0.1, ..., 0.6	
18	Number of singular points (core and delta)	
19	Standard deviation of the ridge flow in the foreground	

Chugh T., et.al, Automatic Latent Fingerprint Value Prediction, IAI 2016

Evaluations

Latent Challenge

- An evaluation based program to strengthen the foundational validity of friction ridge pattern matching, by assessing the performance of
  - current methods and practices examine the limitation of current practices,
  - latent value (quality) assessment algorithms,
  - latent image enhancement techniques.
  - And testing viability of new approaches, and extra information such as higher pixel resolution or pixel depth
- Goal: provide quantitative support to development of standards and statistical models for quantification of the weight of forensic friction ridge patterns.

Expected timeline:
Announce in early 2017. Final report in late 2018.
Now: seeking mated or non-mated latent imagery for testing.

Friction Ridge Collaborative Exercise

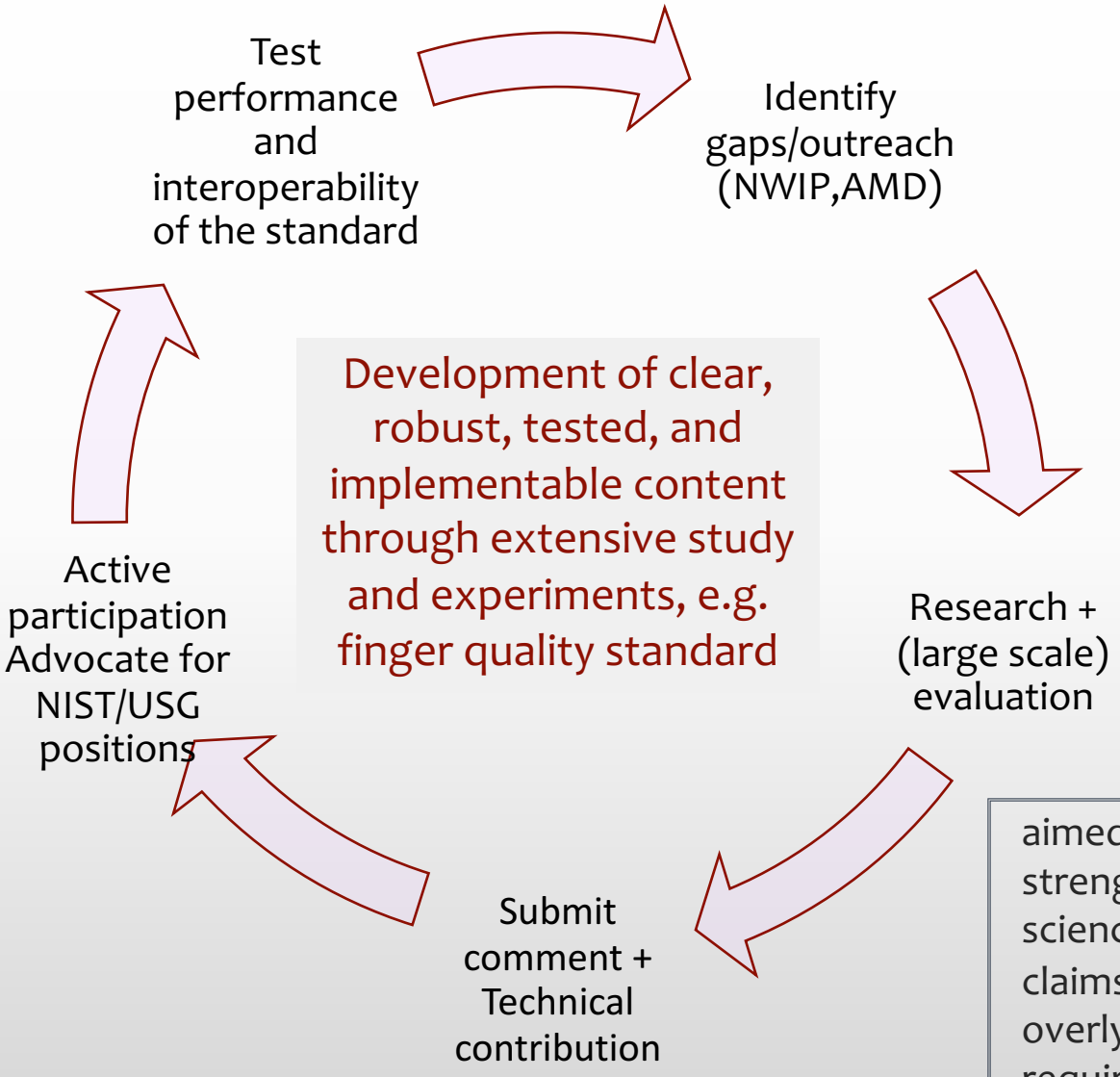
- provide a dataset to the forensic community, and let the community to interpret the dataset and report their findings.

- Broad scope
  - how they setup their analysis (what propositions they make prior to doing their comparisons)
  - how they analyze the dataset and quantify their evidence
  - how they interpret and report the results.

- The results will be presented at NIST workshops.

Seeking input and *data* to get this activity off the ground!

Technical approach::provide quantitative support



aimed at strengthening the science behind the claims or preventing overly prescriptive requirements

Towards objective methods (reduce subjectivity)

Thank You.
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June 27-29, 2017
NIST Gaithersburg Campus

NIST 2017 Technical Colloquium
Weight of Evidence (WoE)

Join us for a discussion about:
defining WoE
data needs and methods for quantifying WoE
understanding and interpreting WoE

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