



**FORENSICS @ NIST**

**#NISTForensics**

# Matching Randomly Acquired Characteristics in Footwear Impressions

Weiying Chen, Martin Herman

Information Technology Laboratory, NIST

# Purpose

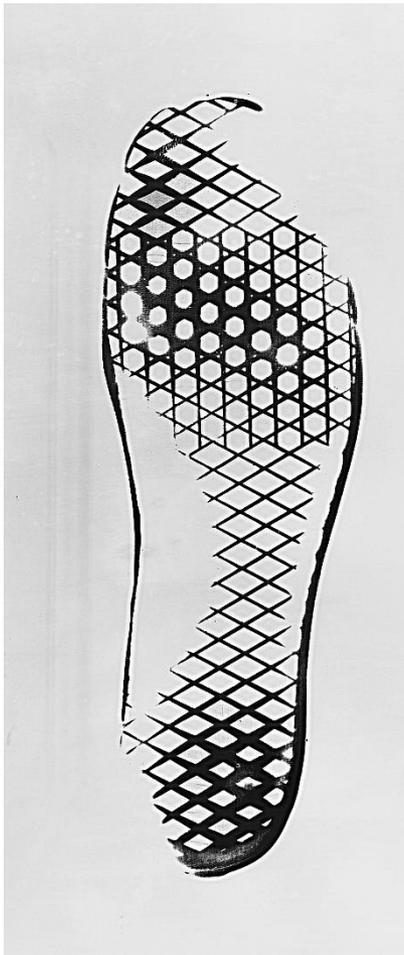
- Obtain a quantitative similarity score for footwear impression comparisons.



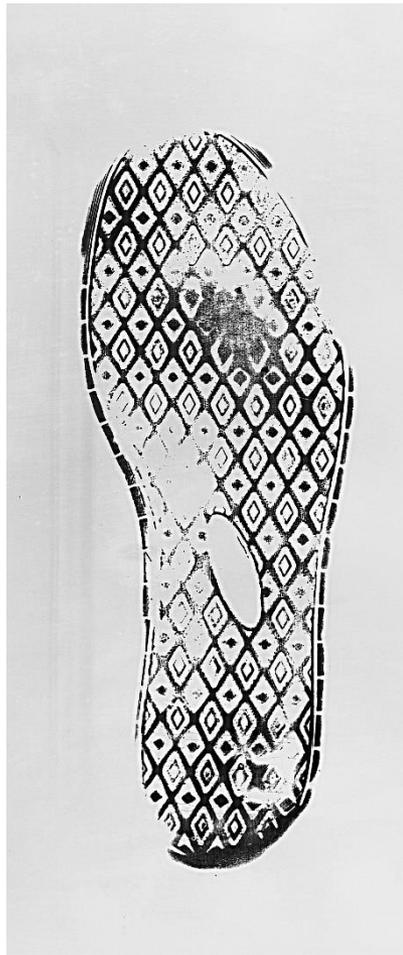
FORENSICS @ NIST

#NISTForensics

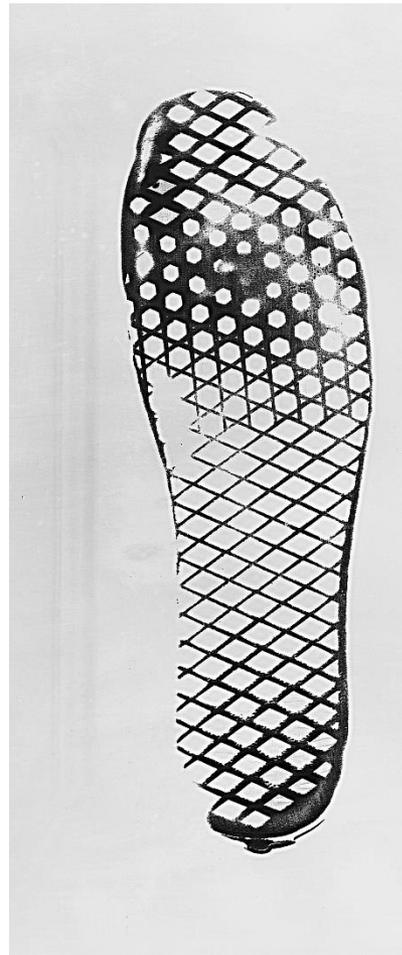
# Class characteristics



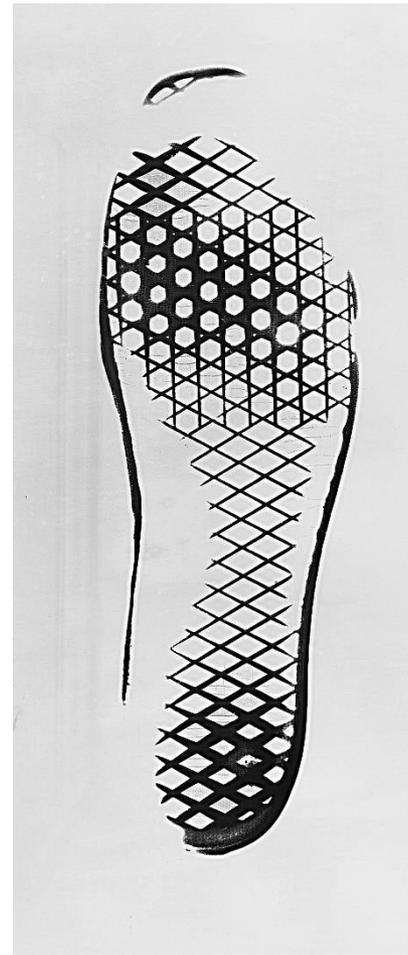
Vans 11



Skechers 9.5



Vans 10.5



Vans 11

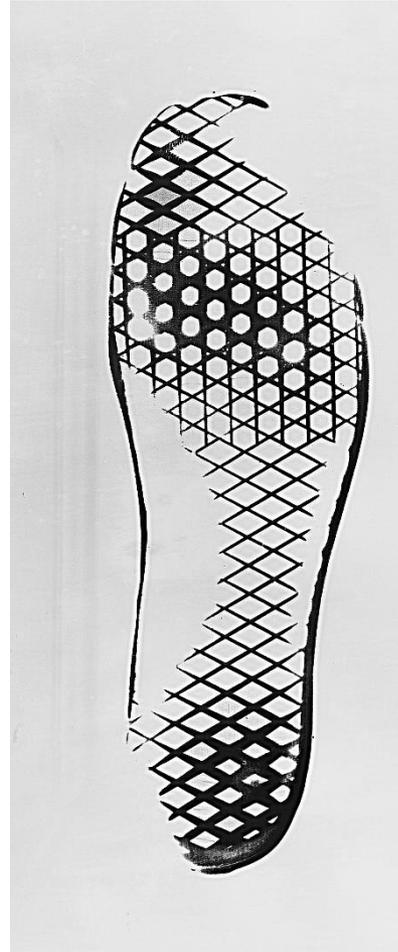


FORENSICS @ NIST

#NISTForensics

# Class Characteristics

- Design(pattern)
- Size
- General wear



Vans 11



Vans 11



# Randomly Acquired Characteristics(RACs)

## Definition

A RAC feature is a feature on a shoe outsole resulting from random events.

- RACs are not replicated in every impression.
- Research has demonstrated that the chance duplication of even one characteristic's position, orientation, shape and size on another shoe of the same size and design would be rare.

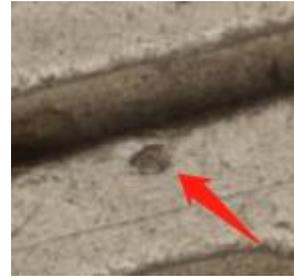
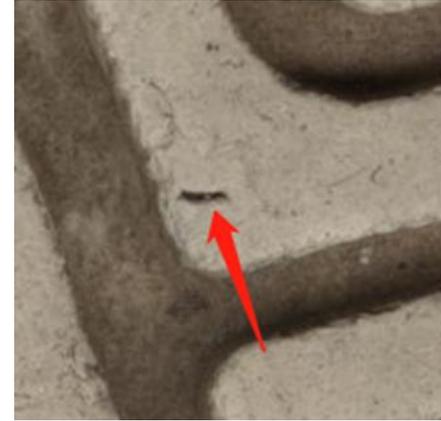


# Randomly Acquired Characteristics(RACs)

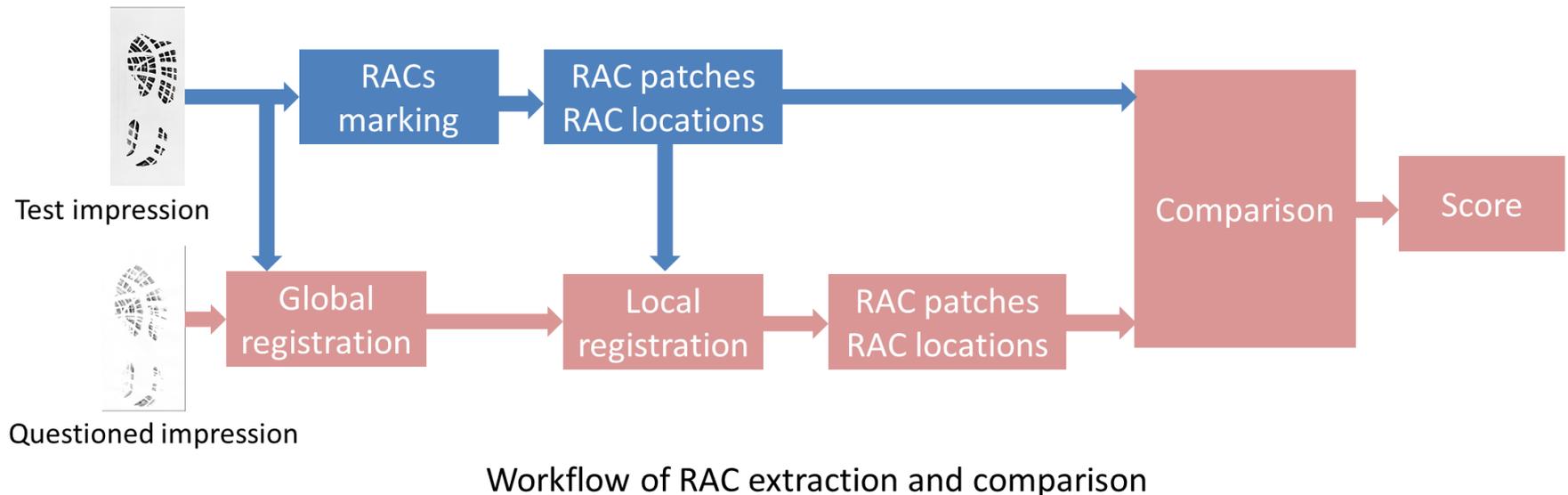
## Types

Include but not limited to:

- Cuts
- Scratches
- Tears
- Holes
- Foreign objects
- Abrasions
- Debris



# Workflow of RACs Comparison



# Global Registration



Test impression



Questioned impression



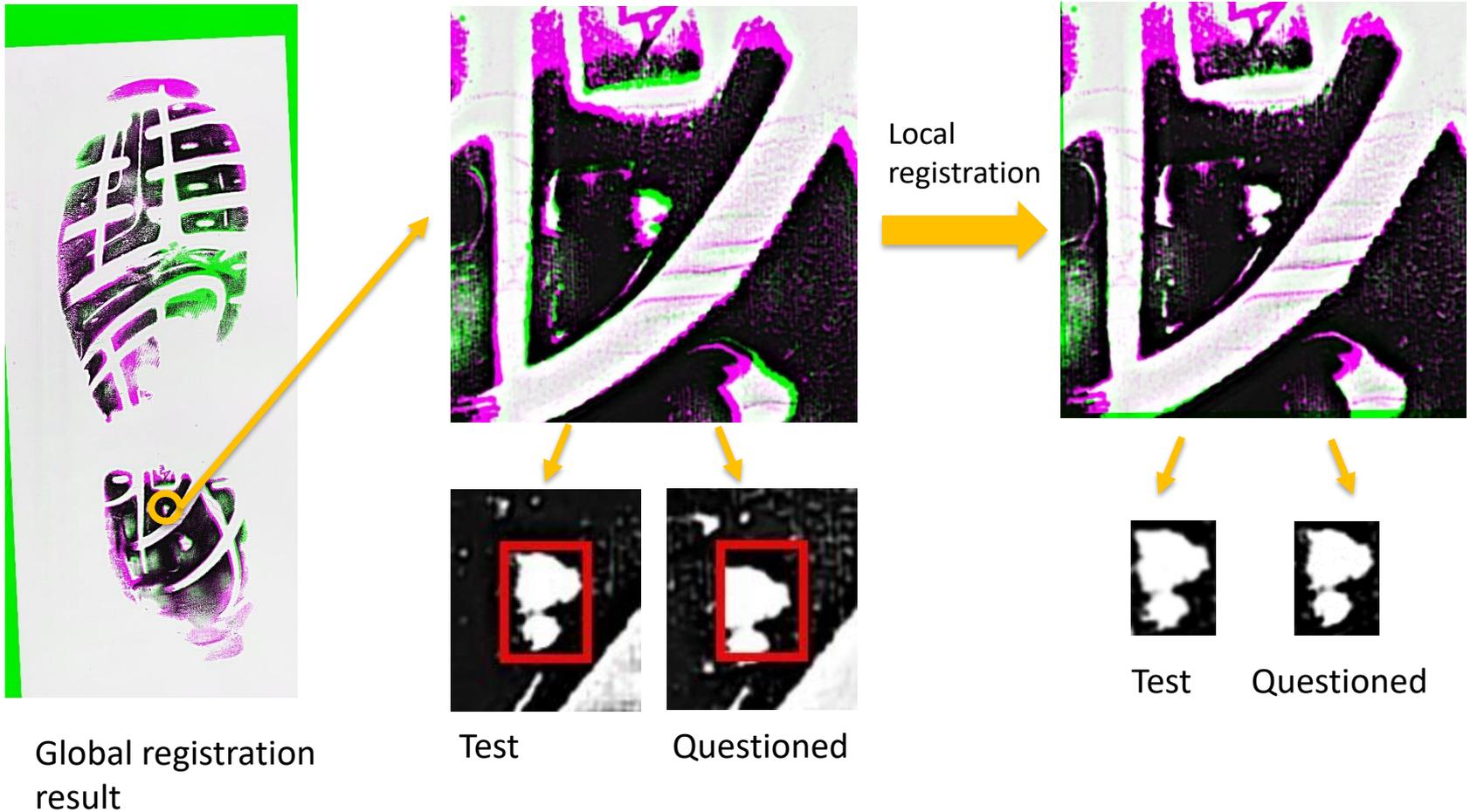
Global registration result



FORENSICS @ NIST

#NISTForensics

# Local Registration



# Registration Methods

## Global Registration

- Principal Axes and Mutual Information
- Point Configuration Methods

## Local Registration

- Mutual Information

$$I(X; Y) = H(X) + H(Y) - H(X, Y)$$
$$I(X; Y) = \sum_x \sum_y p(x, y) \log \frac{p(x, y)}{p(x)p(y)}$$



# Impression comparison based on RACs



Test



Questioned1 (Q1)  
(Mated)



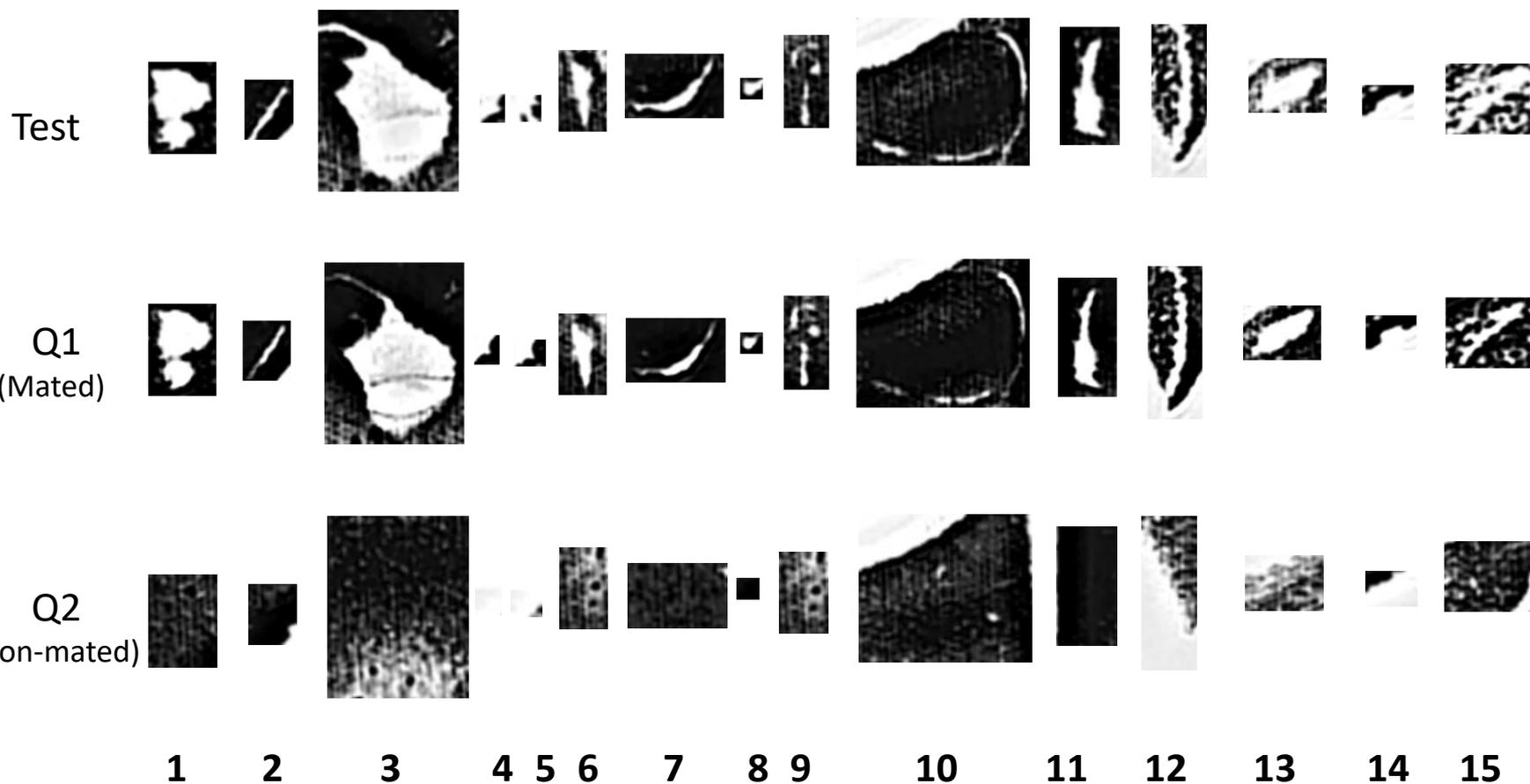
Questioned (Q2)  
(Non-mated)



FORENSICS @ NIST

#NISTForensics

# Impression comparison based on RACs



FORENSICS@NIST

#NISTForensics

# RACs Comparison

## Comparison metric

- Normalized cross correlation

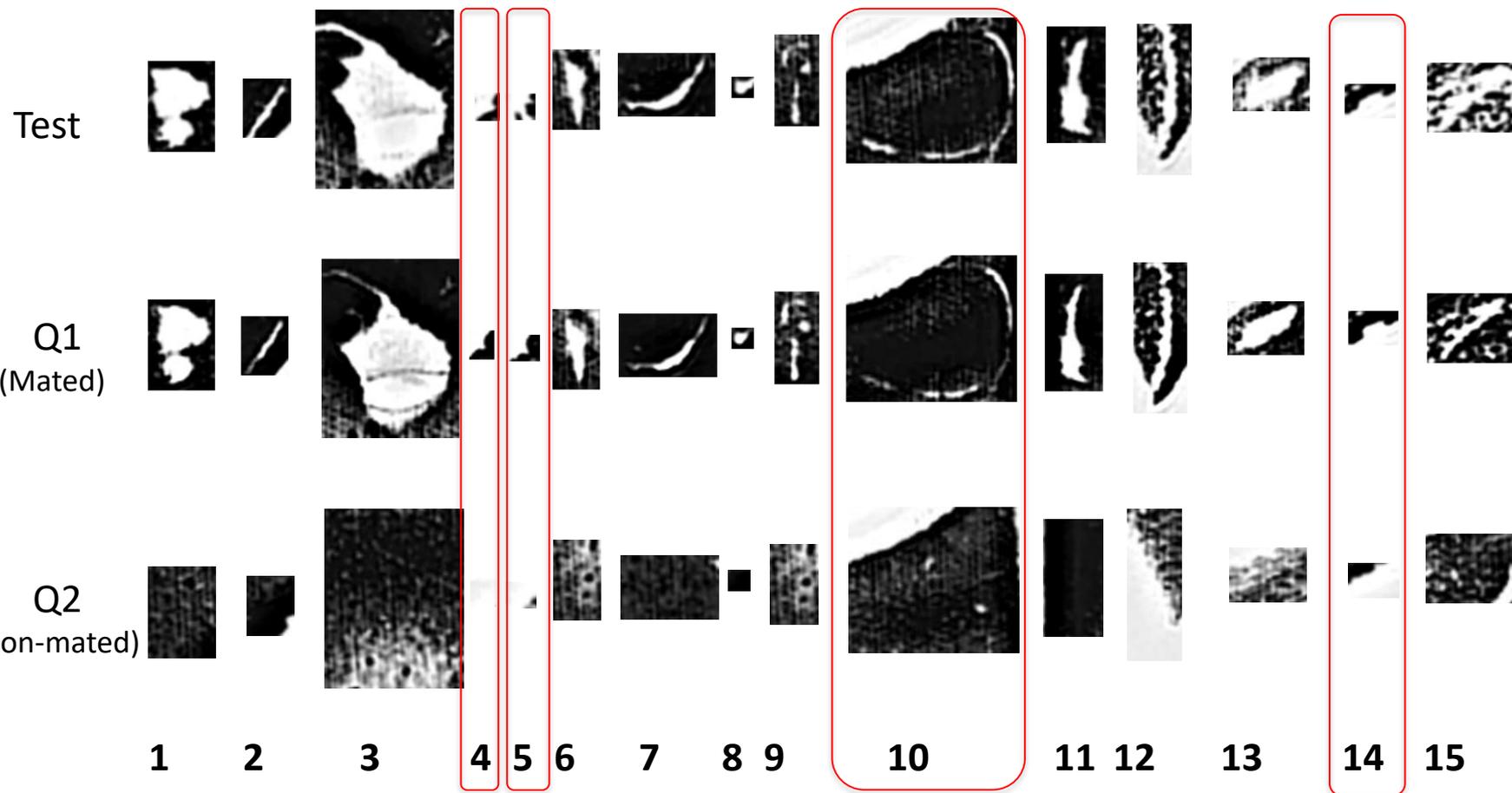
$$r = \frac{\sum_m \sum_n (A_{mn} - \bar{A})(B_{mn} - \bar{B})}{\sqrt{(\sum_m \sum_n (A_{mn} - \bar{A})^2)(\sum_m \sum_n (B_{mn} - \bar{B})^2)}}$$

## Comparison scores

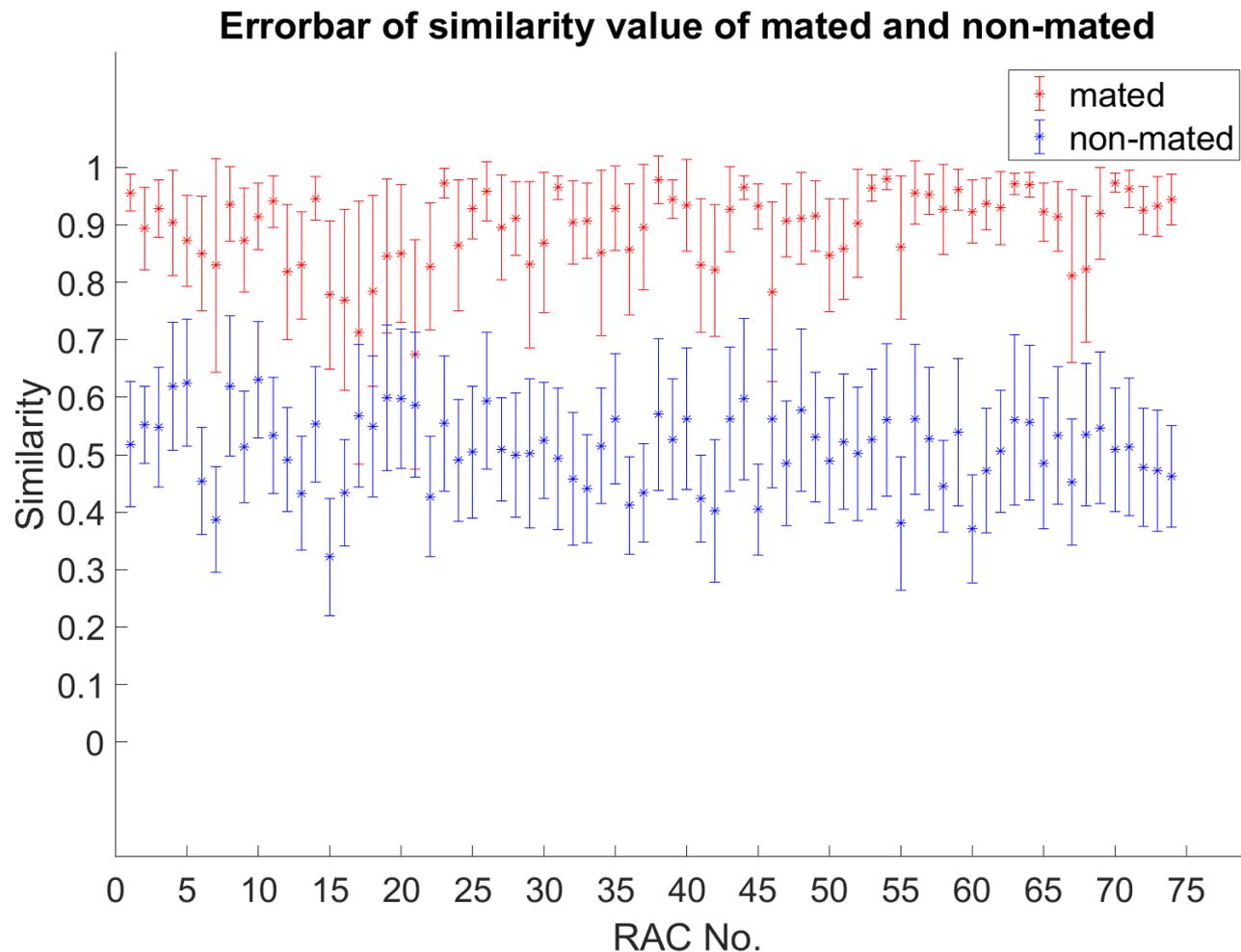
RAC No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Average
Q1 vs Test	0.9400	0.8917	0.8595	0.8617	0.7164	0.8815	0.9105	0.8687	0.8212	0.9152	0.9110	0.8790	0.7357	0.9155	0.6926	<b>0.8534</b>
Q2 vs Test	0.4039	0.5283	0.4779	<b>0.8714</b>	<b>0.8861</b>	0.3849	0.3624	0.6873	0.3329	<b>0.8443</b>	0.5301	0.4497	0.3954	<b>0.8281</b>	0.2596	<b>0.5495</b>



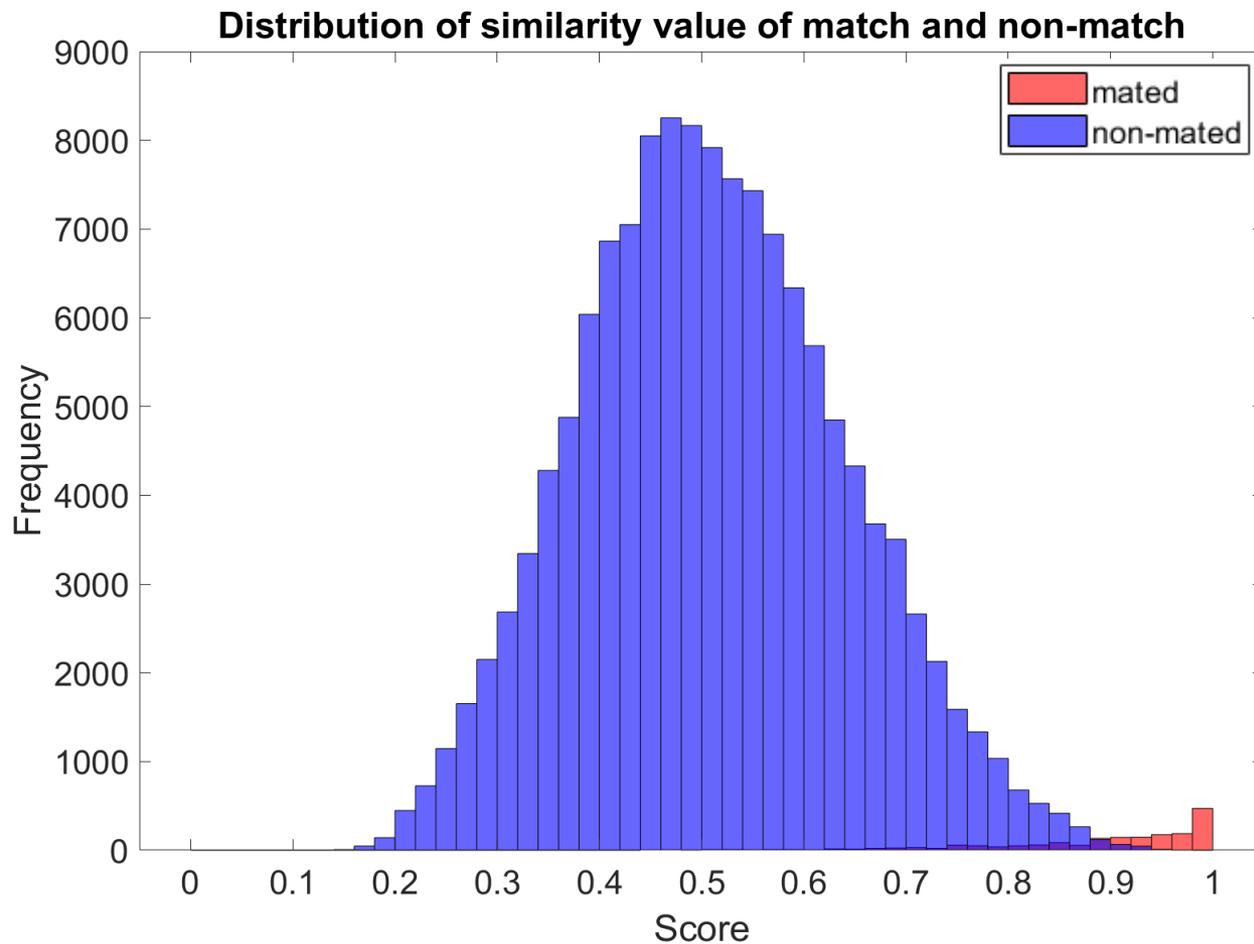
# Impression comparison based on RACs



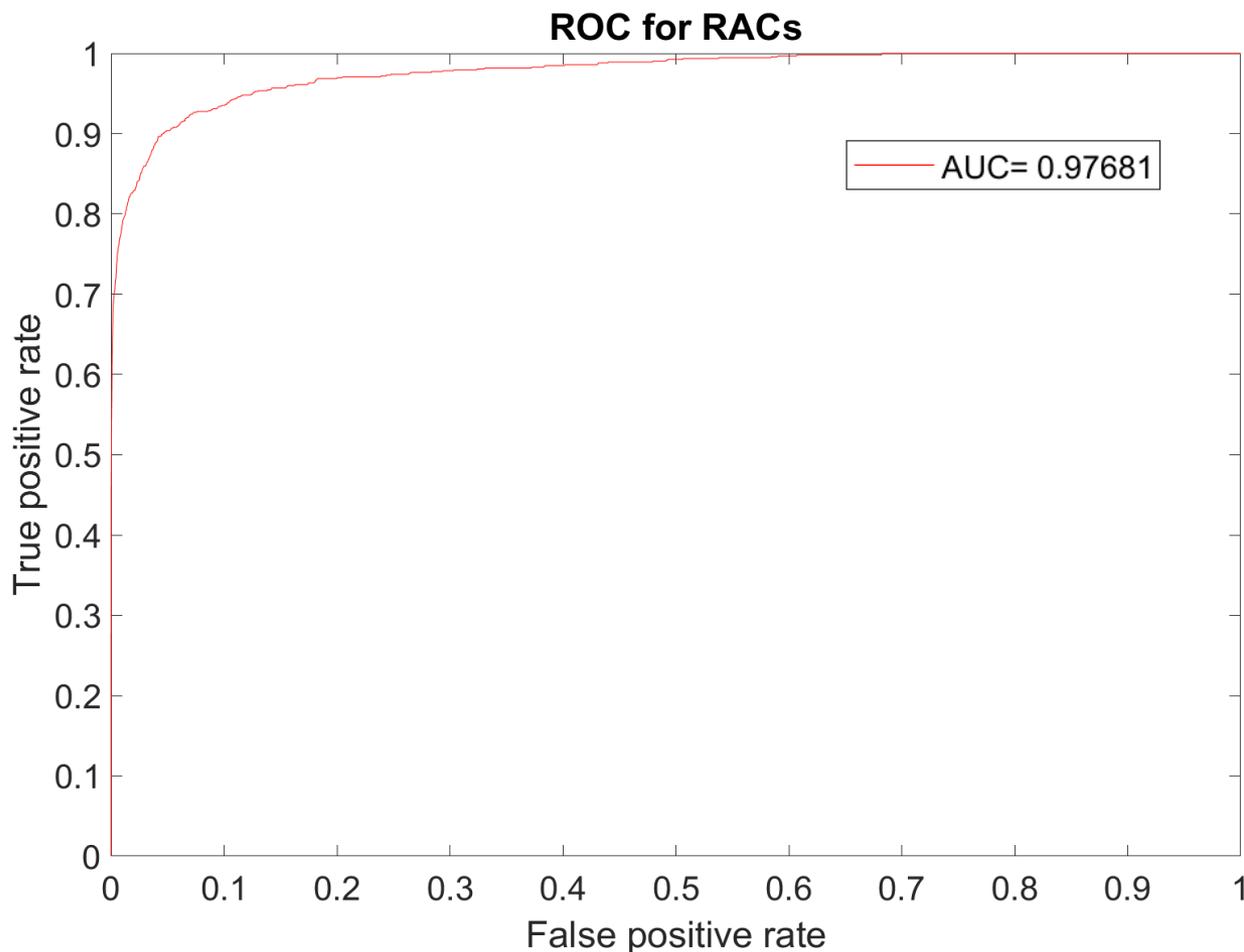
# Performance of the comparison algorithm



# Performance of the comparison algorithm



# Performance of the comparison algorithm



FORENSICS @ NIST

#NISTForensics

# Conclusion

## **Include more information of RACs**

RAC comparison score can help us to give a conclusion of the comparison between questioned impression and known impression according to SWGTREAD range of conclusions scale. The comparison approach used in this presentation is only based on the pixel values of corresponding pixels. The other information of the RACs such as shape, orientation, size will also be incorporated into the similarity score.

## **Find better methods to combine similarity scores of all RAC pairs into a final score**

Different RACs have different importance to the final score due to their different size, shape complexity, orientation and etc.



**FORENSICS @ NIST**

**#NISTForensics**

# Reference

1. William J. Bodziak. Forensic footwear evidence. CRC Press. 2017
2. <https://www.swgtread.org/standards/published-standards>
3. Yoram Yekutieli, Yaron Shor, etc. Expert assisting computerized system for evaluating the degree of certainty in 2D shoeprints. Technical Report. 2016.
4. Josien P. W. Pluim, J. B. Antoine Maintz, etc. Mutual information based registration of medical images: a survey. IEEE Transactions on Medical Imaging. 2003.
5. Jacqueline A. Speir. A quantitative assessment of shoeprint accidental patterns with implications regarding similarity, frequency and chance association of features. Technical report. West Virginia University. Feb. 2018.



FORENSICS @ NIST

#NISTForensics

# Acknowledgement

- We wish to thank **Gunay Dogan, Hari Iyer, Steven Lund, Yooyoung Lee** for helpful discussions.
- We wish to thank our NIST colleagues for donating so many shoes to our team.



FORENSICS @ NIST

#NISTForensics