Similarity between outsole impressions using SURF

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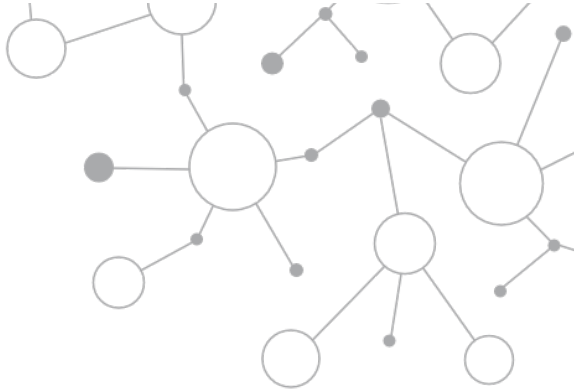
Publication



Park, S. and Carriquiry, A., 2020, **An algorithm to compare 2D footwear outsole images using maximum clique and SURF**, *Statistical Analysis and Data Mining*, In press.

Research funded by the Center for Statistics and Applications in Forensic Evidence (CSAFE) - forensicstats.org

It takes a village

Collaborators:

- Dr. Hari Iyer, NIST
- Sarena Wiesner, Yaron Shor, Israeli Police
- Dr. Guillermo Basulto-Elias, Mr. James Kruse, CSAFE
- Ms. Lesley Hammer, Hammer Forensics
- Dr. Eric Hare, Omni Analytics
- A small army of super smart undergraduates, Iowa State University.

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Goals of presentation

- Introduce an objective method to quantify the similarity between two outsole impressions.
- Show that algorithm is accurate and reliable even when outsoles share class characteristics and degree of wear.
- Show that algorithm is robust even when one image is degraded and partially observed.

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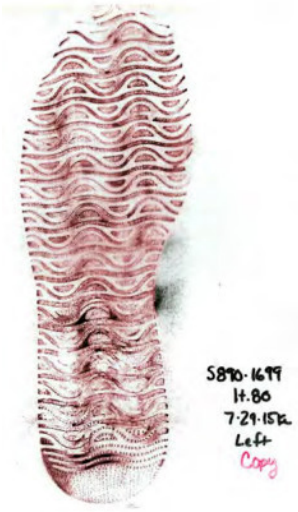
The forensic question

- Could the shoe on the left be the source of the impression on the right?

- Q = questioned
- K = known

Challenging!



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The state of the art

- At present, practitioners rely on training and experience to:
  - Identify features of interest that can be used to compare outsoles.
  - **Subjectively** determine whether outsoles are “similar enough” to suggest same source.
  - Use 7-scale decisions (SWGTREAD)

- Two implicit assessments:
  - How similar are the outsoles?
  - How probative is observed degree of similarity.

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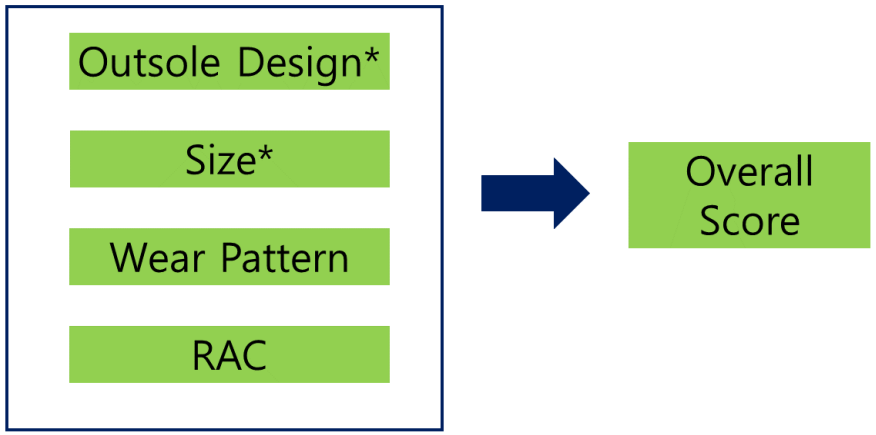
Objective of this project

- Develop a *score* that quantifies the degree of similarity between two outsole 2D images.

- Contributors to the score



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Data collection 1

- CSAFE constructed a longitudinal database of 2D shoe outsole impressions.
- 160 participants were recruited and received a pair of new shoes.
- Participants were asked to use the shoes and return to CSAFE every eight weeks, for six months.

NIKE Winflow 4

Adidas Seeley Skateboard

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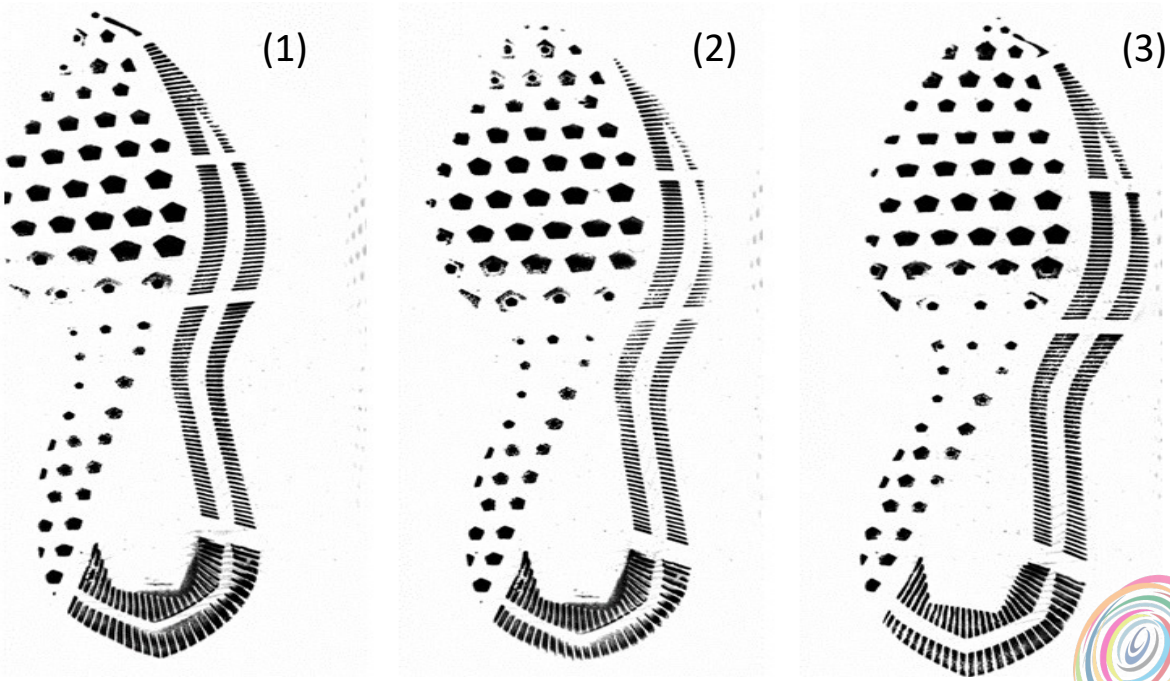
Data collection 2

- Can you visually find the differences?
- Mates: (1) and (2) & Non-mates: (1) and (3)



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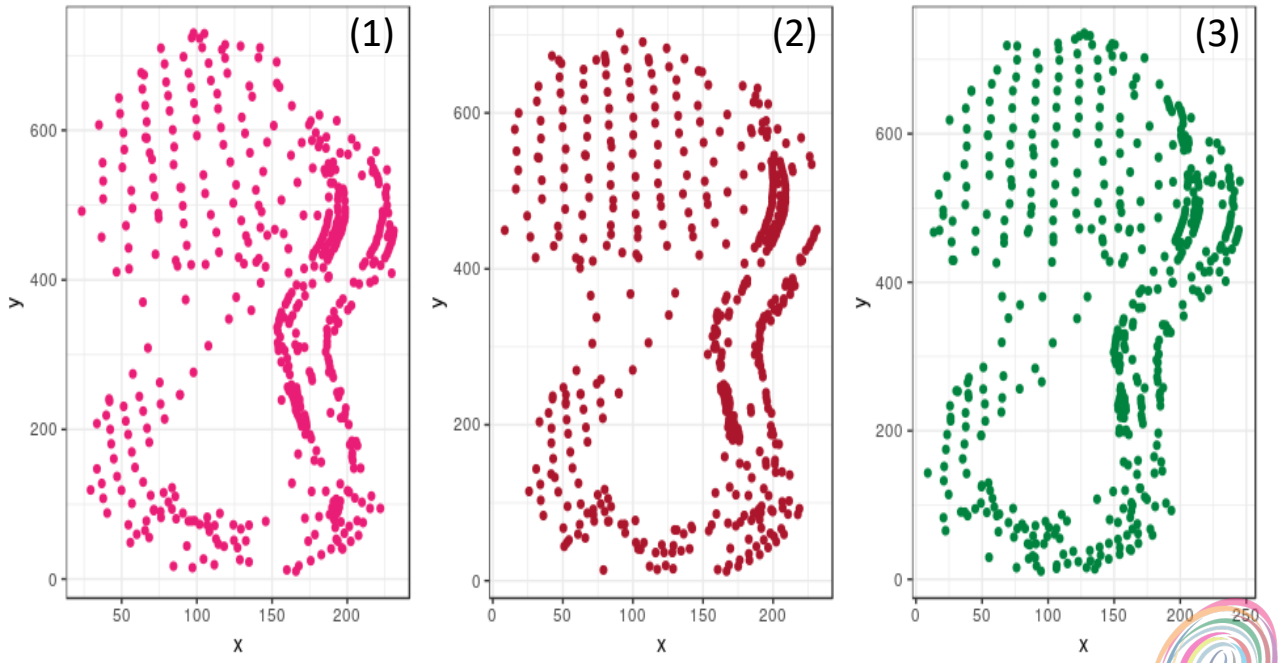
Algorithm I - SURF

- We used the 500 strong SURF (Speeded-Up Robust Features(Bay et al. 2006)) as the points of interest.



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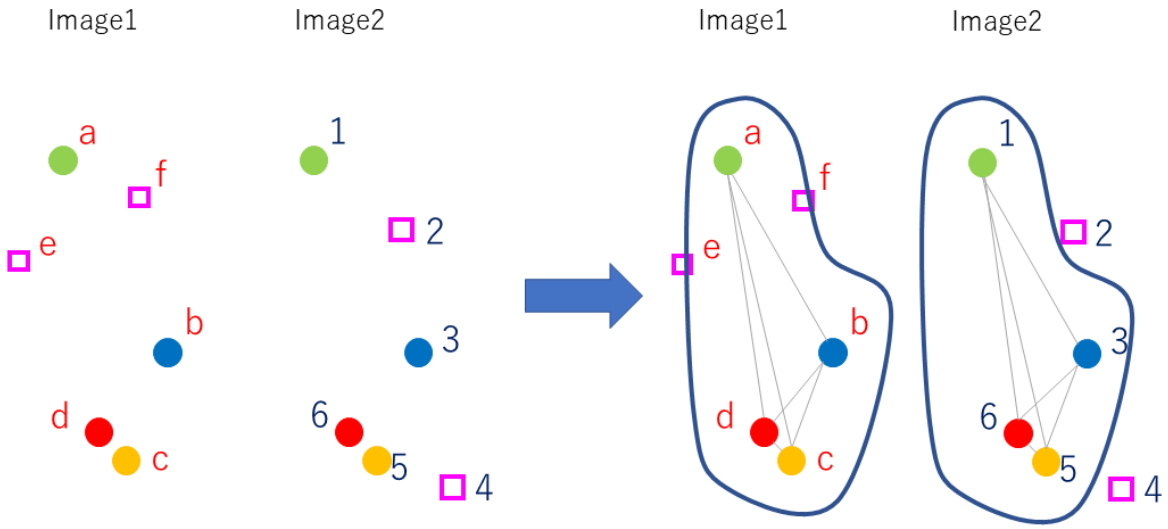
Algorithm II - Alignment

- Maximum clique from the graph theory



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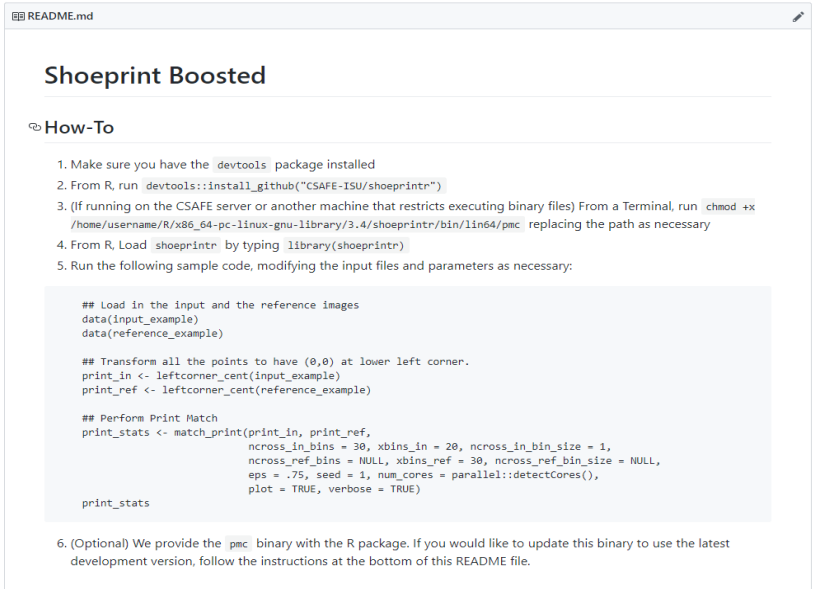
R-package: Shoeprintr

- Delicately developed for image matching using maximum clique
- Parallelized maximum clique with smart sampling
- Visit https://github.com/CSAFE-ISU/shoeprintr



README.md

Shoeprint Boosted

How-To

1. Make sure you have the `devtools` package installed
2. From R, run `devtools::install_github("CSAFE-ISU/shoeprintr")`
3. (If running on the CSAFE server or another machine that restricts executing binary files) From a Terminal, run `chmod +x /home/username/R/x86_64-pc-linux-gnu-library/3.4/shoeprintr/bin/lin64/pmc` replacing the path as necessary
4. From R, Load `shoeprintr` by typing `library(shoeprintr)`
5. Run the following sample code, modifying the input files and parameters as necessary:

```
## Load in the input and the reference images
data(input_example)
data(reference_example)

## Transform all the points to have (0,0) at lower left corner.
print_in <- leftcorner_cent(input_example)
print_ref <- leftcorner_cent(reference_example)

## Perform Print Match
print_stats <- match_print(print_in, print_ref,
                           ncross_in_bins = 30, xbins_in = 20, ncross_in_bin_size = 1,
                           ncross_ref_bins = NULL, xbins_ref = 30, ncross_ref_bin_size = NULL,
                           eps = .75, seed = 1, num_cores = parallel::detectCores(),
                           plot = TRUE, verbose = TRUE)
print_stats
```

6. (Optional) We provide the `pmc` binary with the R package. If you would like to update this binary to use the latest development version, follow the instructions at the bottom of this README file.

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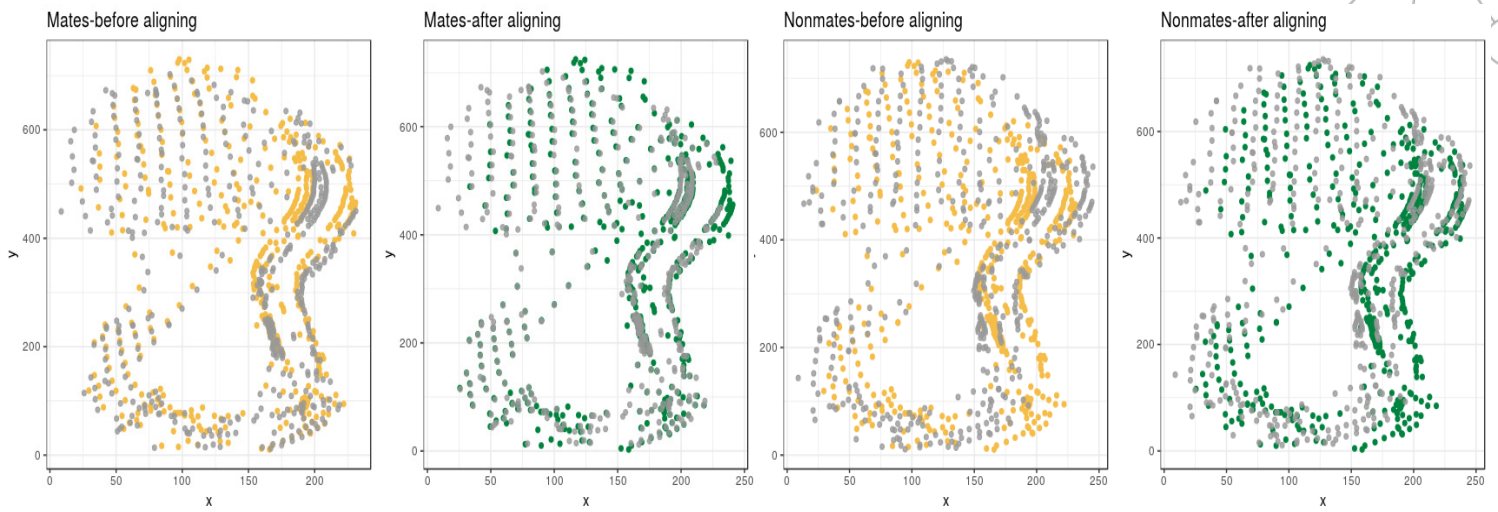
Aligned images



Mates; 56.5% Overlap

Non-mates; 12.1% Overlap

Class	Clique size	Rot. Angle	% Overlap	Med. distance
Mates	18	2.11	56.46%	0.78
Non-mates	9	6.43	12.08%	1.39

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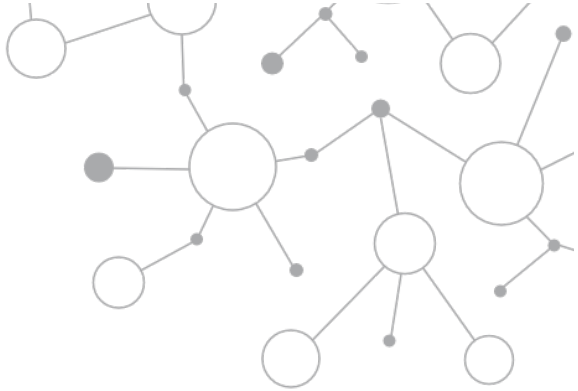
Source prediction performance



- Prediction result by the RF method

	Truth	
Prediction	Mates	Non-mates
Predicted same shoe	277	8
Predicted different shoe	11	196
Total	288	204

- 96% Sensitivity and 96% Specificity
- 4% Error rate

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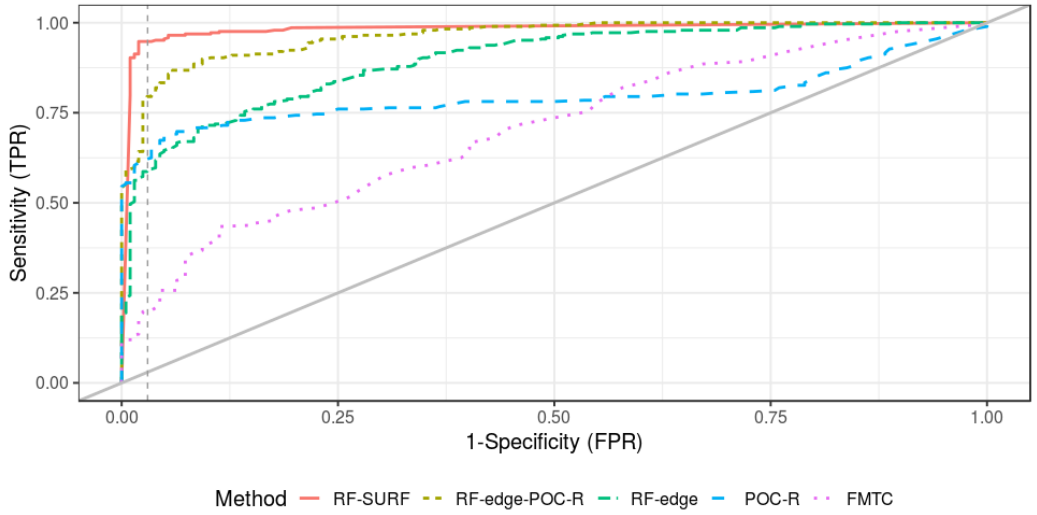
Source prediction performance

- ROC curves



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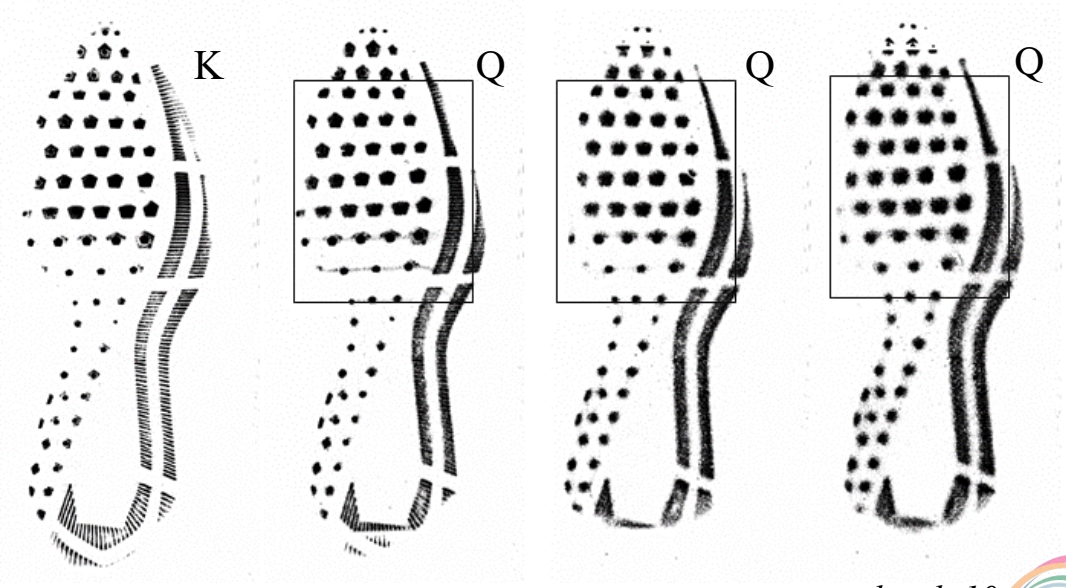
Degraded impressions

- Often, the latent print at the crime scene is blurry or partially observed.
- Q (partial and blurry) vs. K (full and clean)



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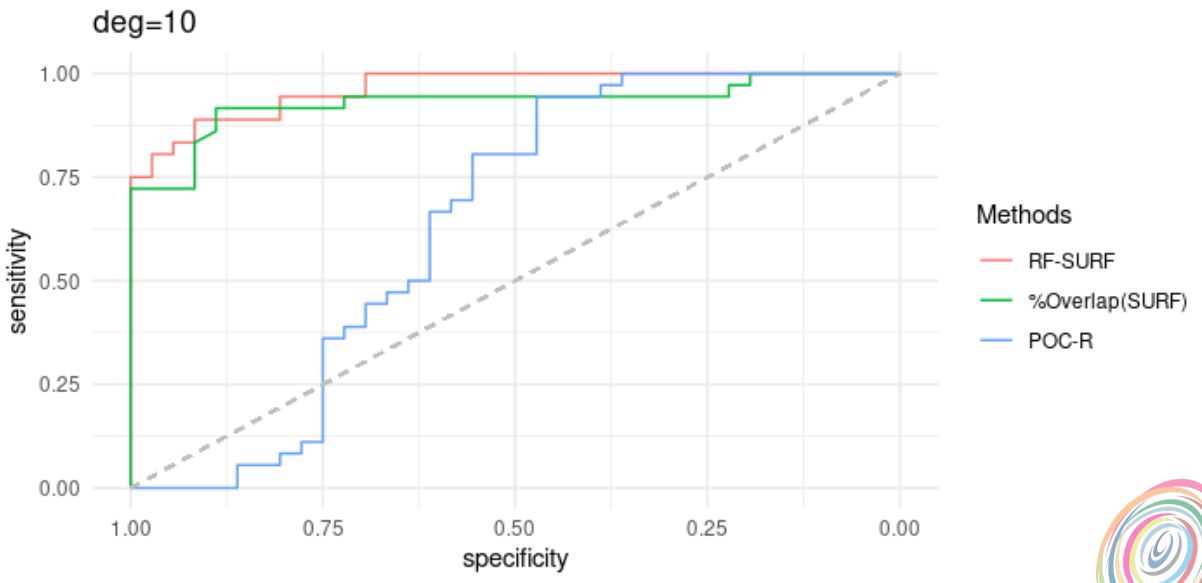
Performance on degraded Q

- ROC curves
- Q *(toe area and level 10 degraded)* vs. K *(full and clean)*
  - False positive rate: 3% -- Incorrectly conclude same shoe
  - False negative rate: 9% -- Incorrectly conclude diff shoe



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Summary

- Automatically finding interesting points in an outsole using SURF appears promising.
- When both impressions are of reasonably good quality, an algorithm based on three features has excellent performance, at least for Nike Airflows and Adidas Steeley.
- When Q is degraded, features no longer serve to predict whether Q and K were made by same shoe.
- **Exception is % points that overlap; this feature is robust on degraded and partially observed images.**

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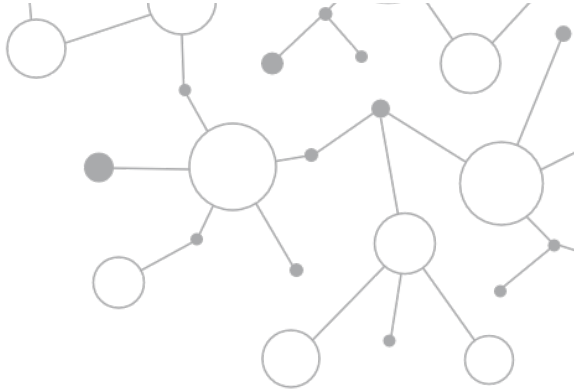
Open questions



- Will algorithms continue to perform well when:
  - We include other brands of shoes (we think yes).
  - Q is degraded in some other way (we need more research).

- Black-box study: compare the outcome of the automated method to the scores produced by a trained examiner.

- Similarity algorithm using convolutional neural network.

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References

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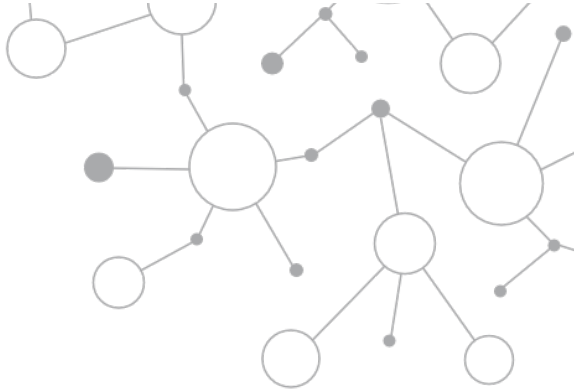
Thanks!



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- Our website:

  www.forensicstats.org

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