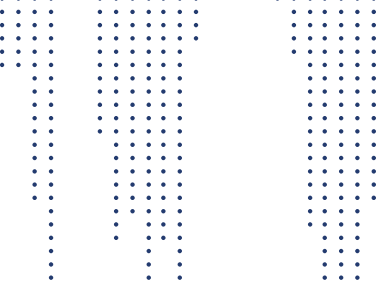


Footwear Impression Analysis

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forensicstats.org



CSAFE 1.0 Accomplishments

- Datasets:
 - Longitudinal database of outsole impression data (160 pairs of shoes worn over 24 weeks, 30k images including test impressions and 2D/3D scans)
 - Shoe outsole imagery database (>200k retail tread photos of 80k products)
- Methods for feature-based matching:
 - Semi-automated score-based matching using random forests
 - Neural network-based feature matching and retrieval from crimescene prints (state-of-the-art performance on public benchmarks)
 - Detecting and cataloging frequencies of tread element types
- Probabilistic models capturing non-uniform spatial distribution of randomly acquired characteristics (RACs)



Research Area Objectives

Overarching goal: *Devise the means to assess the strength of association between a crime scene print and a suspect's shoe and to gather the information that is needed to develop a score-based likelihood ratio framework for footwear examination.*

Objectives:

- Existing models to understand the spatial distribution of RACs rely on simplifying independence assumptions. One goal of our research is to develop and validate models that are more realistic for RACS.
- A limitation in footwear analysis is the absence of reliable, publicly available databases that characterize the distribution of footwear characteristics and patterns.
 - Collect tread product imagery available online to characterize diversity of tread patterns
 - Develop an instrument that can be deployed in public areas to passively collect images of outsoles of shoes. These data can enable estimation of the frequency of footwear patterns in a given region and facilitate the transition to a likelihood ratio or Bayes Factor approach to the evaluation of footwear evidence.
 - Assemble a database of representative simulated crime-scene evidence with known ground-truth
- Extend statistical approaches to feature-based matching of crime scene prints developed during CSAFE 1.0 to be more robust so that they are viable with partial and obscured evidence images.
- Develop evidence quality metrics for footwear impression images that are predictive of matching uncertainty (for either examiners or algorithms) to aid interpretation of footwear evidence.

CSAFE 2.0 Footwear Projects

FW I - Occurrence and Persistence of Accidental Mark Locations On a Shoe Sole

- Lead PI: Hal Stern, UCI

FW II - Statistical Models for the Generation and Interpretation of Footwear Impression Evidence

- Lead PI: Charless Fowlkes, UCI

FW III - Characterization of Footwear in Local Populations

- Lead PI: Susan Vanderplas, UNL

FW IV - Statistical and Algorithmic Approaches to Shoeprint Analysis

- Lead PI: Alicia Carriquiry, ISU, Jacqueline Speir, WVU

******* –Building a Public Dataset of Simulated Crime Scene Impression Evidence**

- All team PIs (cross-cutting)

Ongoing Collaborators and Partners:

Hari Iyer (NIST), Steven Lund (NIST), Martin Hermann (NIST), Sarena Wiesner (Israeli Police), Aviad Levi (Israel Police), Yoram Yekutieli (Hadassah Academic College), Micha Mandel (Hebrew University)

CSAFE 2.0

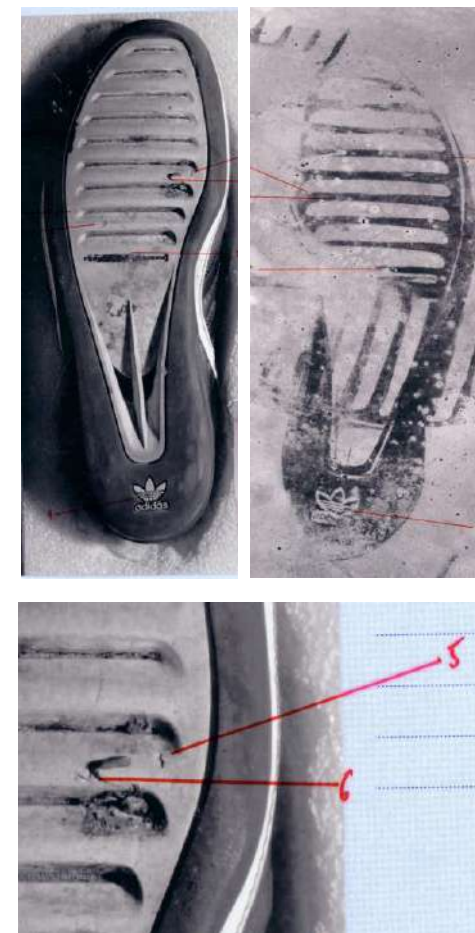
Occurrence and Persistence of Accidental Mark Locations On a Shoe Sole

Proposed Activities:

- Study the reliability of RAC identification, both between-examiner (reproducibility) and within-examiner (repeatability).
 - Methods developed should address location, type, size and shape.
- Collect data (in concert with other FW projects) and use data to understand differences between observed RACs on a shoe and on a crime scene print. Plan to address the following questions:
 - What is the probability of observing a RAC at a crime scene, and how does it depend on the shape, type, size, location and other properties of the physical RAC?
 - How does the probability of observing a RAC depend on the substance and the quality of the trace?
- Build a statistical model to estimate the intensity function of RAC location and account for dependency among RACs and variabilities among individuals

Potential Impact:

- Contribute to the understanding of the scientific strength of footwear comparisons
- Assist in accurate determination of the value of correlation found between the crime scene print and the shoe



CSAFE 2.0

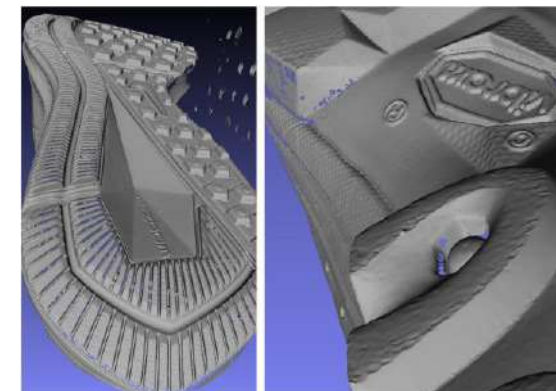
Statistical Models for the Generation and Interpretation of Footwear Impression Evidence

Proposed Activities:

- Develop statistical matching models for reasoning about partial or obscured prints
 - Computational feature matching to provide calibrated match scores of class characteristics from partial prints
 - Generate a large-scale library of tread patterns derived from product imagery to analyze diversity of class characteristics
- Methods for relating three-dimensional (3D) tread shape to impression evidence
 - Models for estimating contact surface and impression likelihood from high-resolution 3D scans
 - Computer vision techniques for estimating contact surface from commercial tread imagery

Potential Impact:

- Statistical basis for better understanding the reliability of impression evidence in determination of class characteristics
- Assistive tools for automatically searching databases of tread patterns and calibrating reliability



CSAFE 2.0



Characterization of Footwear in Local Populations

Proposed Activities:

- Collect footwear data from populations interacting with law enforcement and corresponding general populations.
- Assess class characteristic distribution and variation over time and between populations.

Potential Impact:

- Develop methods to support random match probability calculations for footwear class characteristics.
- Establish differences in reference populations.
- Understand variability in class characteristic frequency related to time and location



CSAFE 2.0

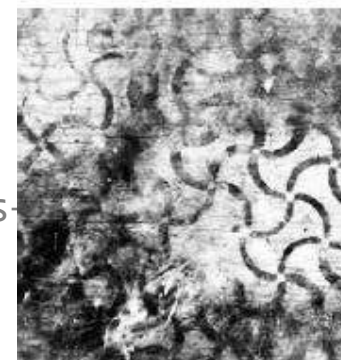
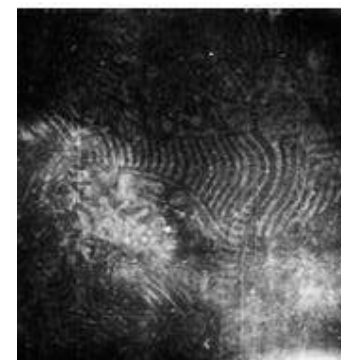
Statistical and Algorithmic Approaches to Shoeprint Analysis

Proposed Activities:

- Continued development of CSAFE 1.0 semi-automated score-based matching techniques
- Propose and evaluate automated image descriptors (noise, texture, frequency, totality, etc.).
- Obtain crowdsourced expert-opinions of image quality.
- Obtain numerical/objective metrics of source association for pairwise comparisons.
- Regress expert-assessed quality and algorithmic similarity with quality metrics in order to assess goodness-
- Create predictive model of image quality for novel imagery.

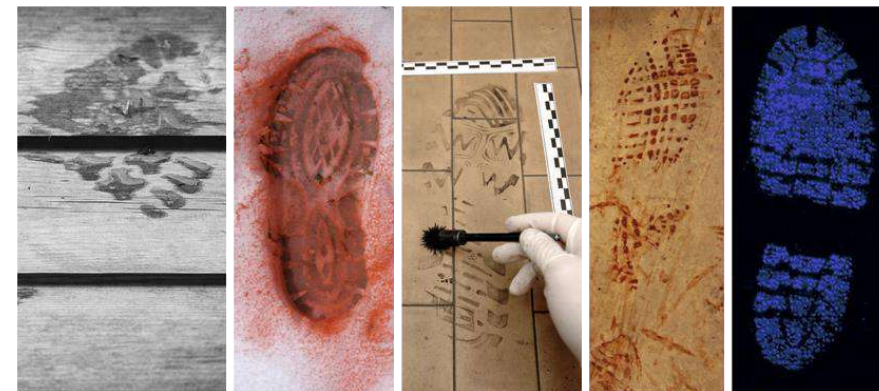
Potential Impact:

This research will inform quality, value and sufficiency predictors that can be used to qualify uncertainty and error estimation in source association conclusions.



CSAFE 2.0

Building a Public Dataset of Simulated Crime Scene Impression Evidence



Planned Activities:

- Assemble a dataset consisting of simulated crime scene evidence with *known-source* test impressions
 - Covering a diverse range of outsole designs, sizes, wear patterns and accidentals
 - Spanning a variety of impression types (dry/wet, chemical enhancement, lifting techniques) and substrates (wood, tile, paper)
 - Generated by a range of activities (e.g., kicking a door, jumping onto a counter, walking, running)
- Prioritize collection of data which is representative of examiner caseloads

Potential Impact:

This effort will provide essential data in support of a wide range of research including impression formation, variability in impressions, repeatability of RAC appearance, evidence quality assessment,

Resources and Needs

Looking for collaborators on:

- Labs and examiners willing to participate in surveys of how frequently different types of evidence, collection techniques and brands of shoes are encountered in typical casework
- Exploring fine grained proficiency testing to understand repeatability / reliability of marking individual RACs
- Correlating retail footwear sales data with distribution of footwear worn by local populations

CSAFE Footwear Resources:

- CSAFE plans to host a footwear workshop in the fall
- Periodic Webinars + Insights
- Datasets and other resources
<https://forensicstats.org/>