Addressing the National Academy of Sciences’ Challenge:

Methods for Statistical Pattern Comparison of Striated Tool Marks
Outline

• Introduction and the Daubert Standard
• Previous Statistical Studies on Striated Tool Marks
• Details of Our Approaches
  • Results of “Low Cost” method
  • Preliminary Results with Confocal Microscopy
Introduction

• DNA profiling the most successful application of statistics in forensic science.
  • Responsible for current interest in “raising standards” of other branches in forensics…??

• No protocols for the application of statistics to comparison of tool marks.
  • Our goal: application of objective, numerical computational pattern comparison to tool marks

Caution: Statistics is not a panacea!!!!
The Daubert Standard

- **Daubert (1993)** - Judges are the “gatekeepers” of scientific evidence.
- Must determine if the science is reliable
  - Has empirical testing been done?
    - Falsifiability
  - Has the science been subject to peer review?
  - Are there known error rates?
  - Is there general acceptance?
- Federal Government and 26(-ish) States are “Daubert States”
Previous Statistical Studies On Striated Tool marks

- Basiotti 1959, **Consecutive Matching Striations**
- Geradts 1994, **TRAX database**
- Neel and Wells 2007, **CMS testing**, 4000 striated tool mark comparisons.
  - “There is a statistically significant difference between the CMS runs observed in the best KNM and the most conservative KM.”
  - Database of striated tool mark profiles and corresponding software for identifications
Previous Statistical Studies On Striated Tool marks

• Howitt, Tulleners et al. (2008)
  • A theory for striation patterns
• Bachrach, Koons et al. (2010),
  • Screwdrivers and Pliers
  • ID software for use with confocal microscopy
• Wei, Vorburger, Ballou, et al. (2010)
  • L.E.A.s on bullets
  • Also ID software for use with confocal microscopy
“Low cost” Approach For Striated Tool Marks

- Collect several high quality 0.25” slotted screwdrivers
  - All screwdrivers purchased in packages of three
• Generate many standard reproducible striation patterns for each screwdriver.
  • Modeling clay used as impression medium
• Measure line/grove positions from edges of patterns
• Descritize width of pattern into 0.05 mm increments
  • In list 140 increments long (7 mm) record 1 if line/grove in a box, 0 otherwise
  • Gives 140-dimentional **feature vectors** for each pattern
• Slightly shift intra-screwdriver patterns if necessary (registration)

• For this study:
  • Nine screwdrivers so far
  • Data recorded for side A of screwdrivers
    • Screwdriver 1, 8 striation patterns
    • Screwdriver 2, 6 striation patterns
    • Screwdriver 3, 9 striation patterns
    • Screwdriver 4, 8 striation patterns
    • Screwdriver 5, 9 striation patterns
    • Screwdriver 6, 9 striation patterns
    • Screwdriver 7, 8 striation patterns
    • Screwdriver 8, 9 striation patterns
    • Screwdriver 9, 9 striation patterns
  • Total 75 striation patterns so far
Statistics

- Principal Component Analysis
  - Why?
    - Judges and Juries Like Pictures!!
- Kernel Partial Least Squares

- Find lowest dimensional “summary” of striation pattern that is still able to predict screwdriver identity.

\[ \hat{Y} = \hat{X}Q^T + \text{Err} \]

Classification of Screwdriver 5 in 24D
Determine efficient decision rules in the absence of any knowledge of probability densities for the data

- Maximum margins of separation, SVM:

- 4D PCA-SVM
  - Range of estimated error rates: 0%-2%

- 8D PLS-DA
  - Range of estimated error rates: 0%-3%
• Conformal Prediction Theory
  
  • New, but has roots in 1960’s with Kolmogorov’s ideas on randomness and algorithmic complexity.
  
  • Can be used with any statistical pattern classification algorithm.
  
  • Independent of data’s underlying probability distribution.
    • This is a very important property for forensic tool mark analysis!!
  
  • For identification of patterns, method produces:
    • Level of confidence, 1-ε
      • Measure of how likely identification is to be correct
    • Level of credibility
      • Indicative of quality of data set
  
  • Results are valid: \( P(\text{error}) \leq \varepsilon \)
Conformal Prediction Theory

- 95% CPT on 3-nearest neighbour classification rules

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- 95% CPT on PCA-SVM classification rules

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Current Approach For Striated Tool Marks

- Obtain striation pattern profiles from 3D confocal microscopy
• 3D confocal image of entire shear pattern
Shear marks on primer of two different Glock 19s
Shear mark on different cartridge casings from *same* Glock 19
Mean profile:

“Waviness” profile:

“Roughness” profile:
• 3D PCA-SVM Bootstrap error rate ~1%:
Acknowledgements

• National Institute of Justice
• New York City Police Department Crime Lab
• John Jay College of Criminal Justice

• Research Team:

  • Mr. Peter Diaczuk
  • Ms. Carol Gambino
  • Dr. James Hamby
  • Dr. Thomas Kubic
  • Mr. Jerry Petillo
  • Mr. Nicholas Petraco
  • Dr. Peter A. Pizzola
  • Dr. Jacqueline Speir
  • Dr. Peter Shenkin
  • Mr. Peter Tytell

  • Helen Chan
  • Manny Chaparro
  • Aurora Ghita
  • Frani Kammerman
  • Brooke Kamrath
  • Loretta Kuo
  • Dale Purcel
  • Rebecca Smith
  • Elizabeth Willie

• Chris Singh
• Melodie Yu