Adapting the Chumbley Score to match Bullet Striations

Ganesh Krishnan and Heike Hofmann, Department of Statistics, Iowa State University

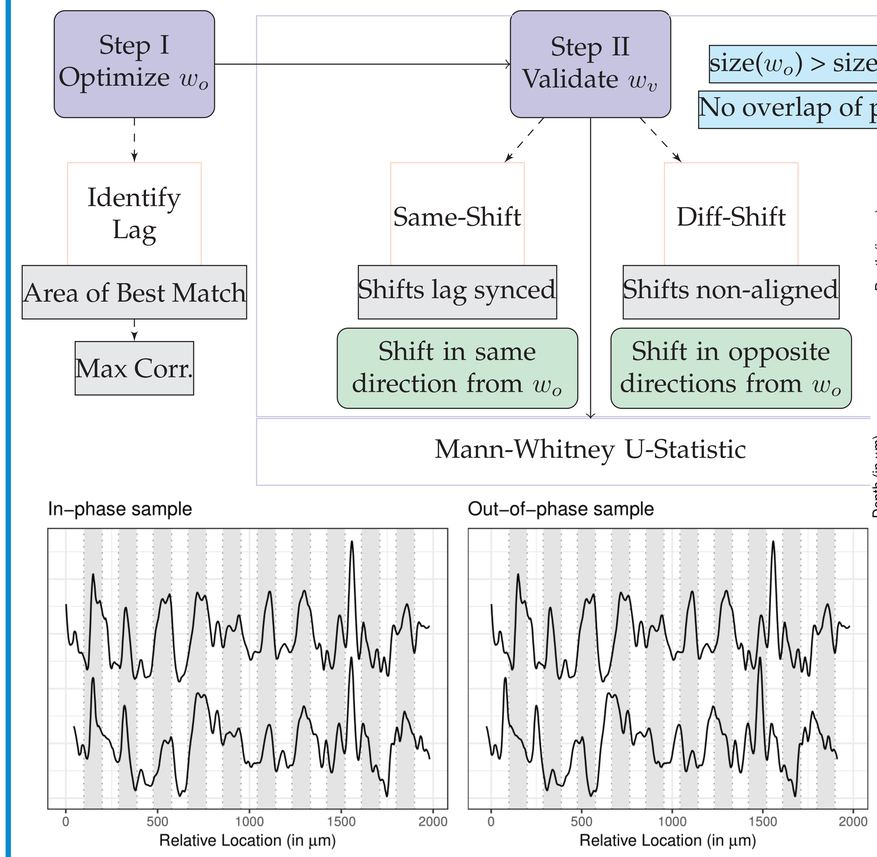
Objectives

Bullet Matching Are two bullets fired from the same gun? Do methods proposed for tools and toolmarks work well for bullets? We choose a statistical method based on a non-parametric test [1] and evaluate its performance on bullet striation marks by doing land-to-land comparisons. This investigation aims to identify the error rates for bullet striations especially how different parameters of this algorithm affects the error rates.

Introduction

In this study we conduct same source matching of bullet lands using the adjusted Chumbley method [2], on all pairwise land-to-land comparisons of the Hamby scans [3] provided by NIST [4] (85,491 comparisons). The comparisons are carried out for a range of optimization w_o and validation window w_v sizes, as well as smoothing levels. The testing setup allows determination of optimum settings that minimize error rates, enabling us to justify its use on bullets.

Comparison of Bullet Striations

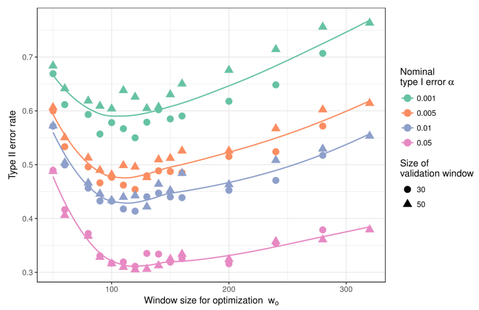


Digitized striations [5]

Each window ≈ partial segment of striation

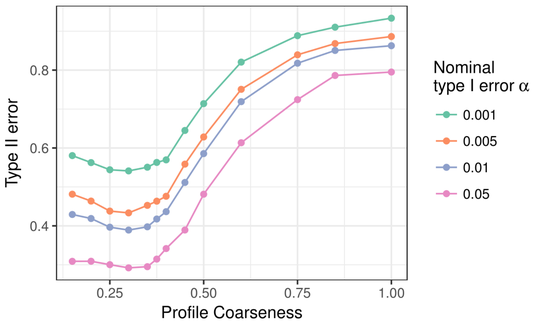
Correlation of corresponding windows in the two marks: Step dependent

False Negative rates

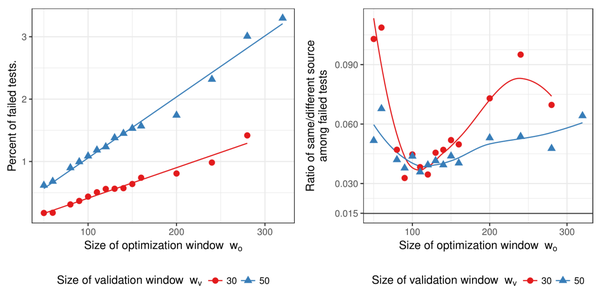


- The Type II error is at best 30 % for a type-I error rate of 5 % size(w_o) = 120 and size(w_v) = 30
- This is well above the error rates for toolmarks from screw drivers. [1, 2]
- Smaller sizes of w_v are typically associated with a smaller type II.

- LOWESS smoothing of profiles at different levels with w_o and w_v sizes as 120 and 30.
- Type II error for all nominal levels of α is lowest for a coarseness $c \approx 0.3$
- Significant increase in error rates for higher c

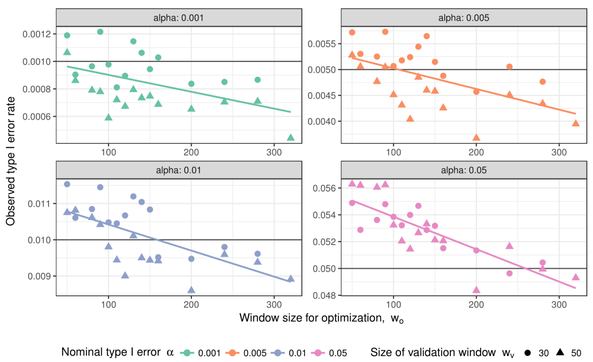


Failed tests and False Positive rates



- Number of failed tests increases with an increase in the size of the w_o (top left).
- Dependency between failed tests & ground truth
- For the ratio of the number of land pairs from same and different sources (top right), same-source comparisons fail at twice the rate (even for the minimum) of what they are expected to (horizontal line).

- Observed type-I error is generally close to the nominal type-I error rate.
- Type-I error decreases as the size of w_o increases
- May be related to the increasing number of failed. tests for larger window sizes particularly for non-matching striations.



Conclusions and Future Research

- Error rates higher for bullets than for screwdriver toolmarks [2] using the adjusted chumbley method.
- For the NIST [4] scans, method best works for w_o and w_v of 120 & 30 with a coarseness $c \approx 0.3$. For a nominal α of 5%, the Type I rate is **5.4 %** and the Type II rate is **30 %**.
- Using scans from CSAFE at higher resolution ≈ longer digitized markings for comparison
- Bullet-to-bullet comparisons and Modify algorithm to include wiggle room in comparison windows.

References

[1] L. Scott Chumbley, Max D. Morris, M. James Kreiser, Charles Fisher, Jeremy Craft, Lawrence J. Genalo, Stephen Davis, David Faden, and Julie Kidd. Validation of tool mark comparisons obtained using a quantitative, comparative, statistical algorithm. *Journal of Forensic Sciences*, 55(4):953–961, 2010.

[2] Jeremy R. Hadler and Max D. Morris. An improved version of a tool mark comparison algorithm. *Journal of Forensic Sciences*, 2017.

[3] James E. Hamby, David J. Brundage, and James W. Thorpe. The Identification of Bullets Fired from 10 Consecutively Rifled 9mm Ruger Pistol Barrels: A Research Project Involving 507 Participants from 20 Countries. *AFTE Journal*, 41(2):99–110, 2009.

[4] Xiaoyu Alan Zheng. NIST Ballistics Toolmark Research Database (NBTRB), 2016. [Online; accessed 19-March-2018].

[5] Eric Hare, Heike Hofmann, and Alicia Carriquiry. Automatic Matching of Bullet Lands. *Annals of Applied Statistics*, January 2016.