Adapting the Chumbley Score to match Bullet Striations

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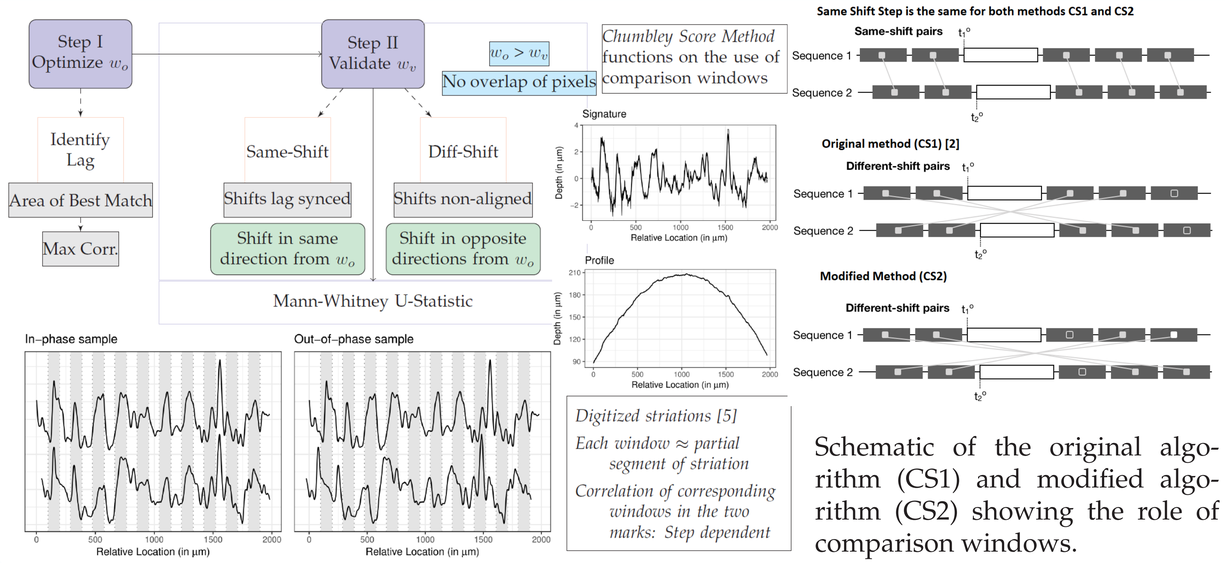
Objectives

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

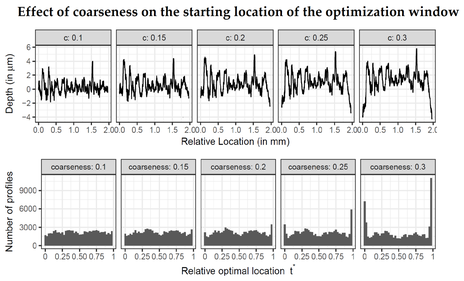
In this study we conduct same source matching of bullet lands using the adjusted Chumbley method [2], on all pairwise land-to-land comparisons of the Hamby scans [3] provided by NIST [4] & CSAFE (85,491 comparisons). The comparisons are carried out for a range of optimization w_o and validation window 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.

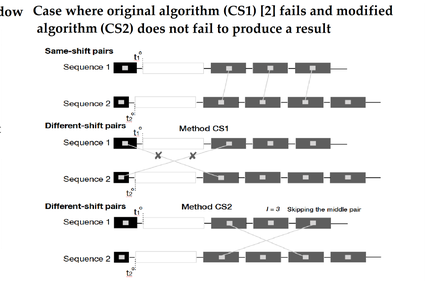
Overview of Chumbley Score Algorithms

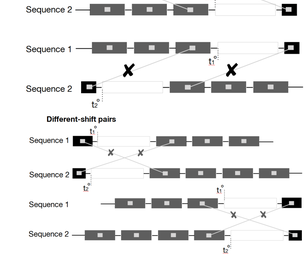


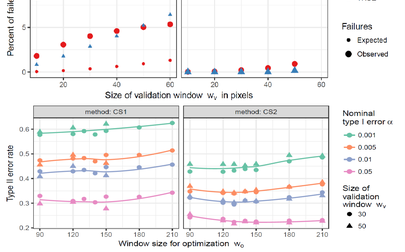
Schematic of the original algorithm (CS1) and modified algorithm (CS2) showing the role of comparison windows.

The Case of Failed Tests



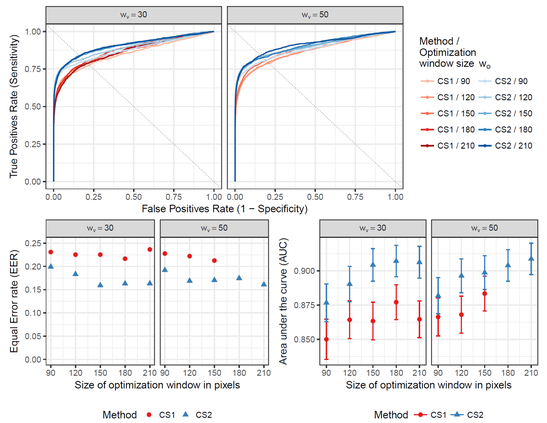


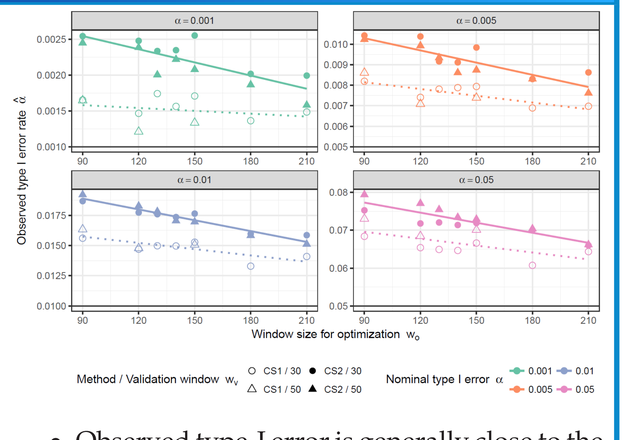




- Optimal locations are distributed uniformly once (sub-)class characteristics are removed. For c > 0.20 we see quite distinct boundary effects
- The key effect of the optimal locations and thereby coarseness is seen in the number of failed tests.
- For w_o = 120 & coarseness c = 0.25, the % of failed tests is much smaller under CS2. Observed failure rates of CS1 are higher than expected rates.
- Min type II error rate of 21.7% seen at w_o = 130 for CS2. Smaller w_v are typically associated with smaller false negatives.

Error Rate assessment





- ROC: Superior performance for CS2 over CS1
- $w_o \geq 150$ pixels leads to the best performance. $w_v = 30$ shows better results than $w_v = 50$.
- EER reduced while AUC significantly increases (at $\alpha = 0.05$) using method CS2 vs CS1.
- Observed type-I error is generally close to the nominal type-I error rate. Decreases as w_o increases.
- May be related to the increasing # 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 [1][2] using the method CS1 [2].
- The coarseness parameter in particular has a strong impact on the performance of the test. For bullet lands we found $c = 0.15$ suitable for the low-resolution scans from NIST and $c = 0.125$ suitable for the higher-resolution scans from CSAFE.
- For the NIST [4] scans, CS1 [2] method best works for w_o and w_v of 140 & 30. The minimum Type II rate is **27.2 %**, for a nominal α of 5%.
- Type II error rates using the modified method (CS2) showed an improvement of more than 20% points over the performance of the algorithm CS1 [2] (for a Type I error of 0.05). Thereby also increasing the power of the test.
- CS2 algorithm introduced here, achieves on average, a ten-fold reduction in the number of failures.
- **Future work:** Bullet-to-bullet comparisons to further increase the power of the test.

References

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