A Factorial-Design Database of 3D Screwdriver Striation Marks for Objective Toolmark Identification

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1. Project Rationale & Goals

Project Rationale:
Forensic toolmark examiners need a statistical method for analyzing marks made by handheld tools. They also need more databases of toolmarks that have been generated under controlled conditions to study the validity of toolmark comparisons.

Goals:
1) Database: Create a high-quality database of toolmarks. In this project we will create a database of toolmarks by using screwdrivers – one of the simplest tools that is commonly used in crimes and that can serve as an initial step in statistical models of toolmark examination.

2) Algorithm: Develop an algorithm to compute a likelihood ratio: the likelihood of the similarity assuming both toolmarks came from a common source and the likelihood of the similarity assuming the toolmarks were made by different tools.

3) Validation: Evaluate the algorithm's external validity.

2. Materials & Methods

Materials:
- Mechanical rig (Fig. 1): Rig that can generate screwdriver toolmarks by holding force, speed, and angle constant.
- Screwdrivers (Fig. 2): 20 small, 20 medium, 20 large screwdrivers that were consecutively manufactured by Klein tools.
- 3D microscope (Fig. 3): Handheld scanner from GelSight. This scanner can be pressed against toolmarks to scan them and generate 3D images.
- 3D scan (Fig. 4): Visualization of a 3D toolmark in lead after scanning with the GelSight scanner and applying RStudio bulletxtrctr package.

Figure 1: Mechanical rig

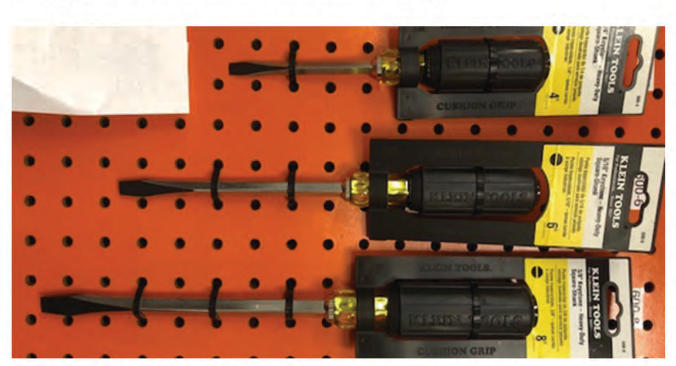

Figure 2: 60 Consecutively manufactured screwdrivers

Figure 3: 3D microscope

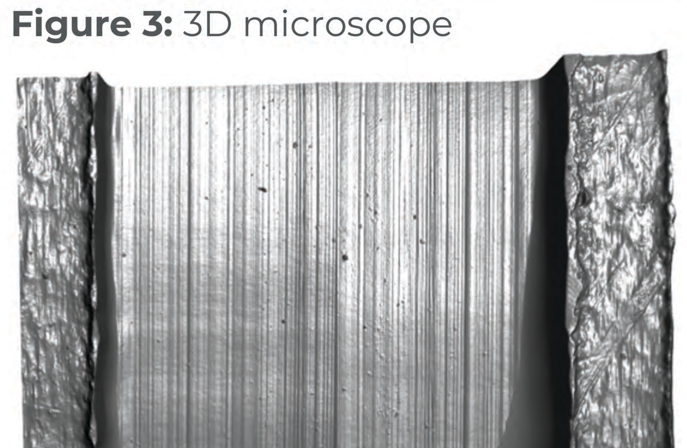

Figure 4: 3D Toolmark scan in lead

Methods:
- Clustering: We are using clustering algorithms with different distance measures to classify marks made by the same screwdriver, using untrained data. This helps as a comparison to the Bayesian model.
- Bayesian model: We are fitting a model that adapts to including progressively more data. We estimate parameters that characterize the "signature" of each screwdriver (both sides). The model also characterizes the variation within tool as well as the variation between tools.

Scan Me! See how we make toolmarks!

Scan Me! See how we scan toolmarks!

3. Results

Fig. 5 Angle Comparison

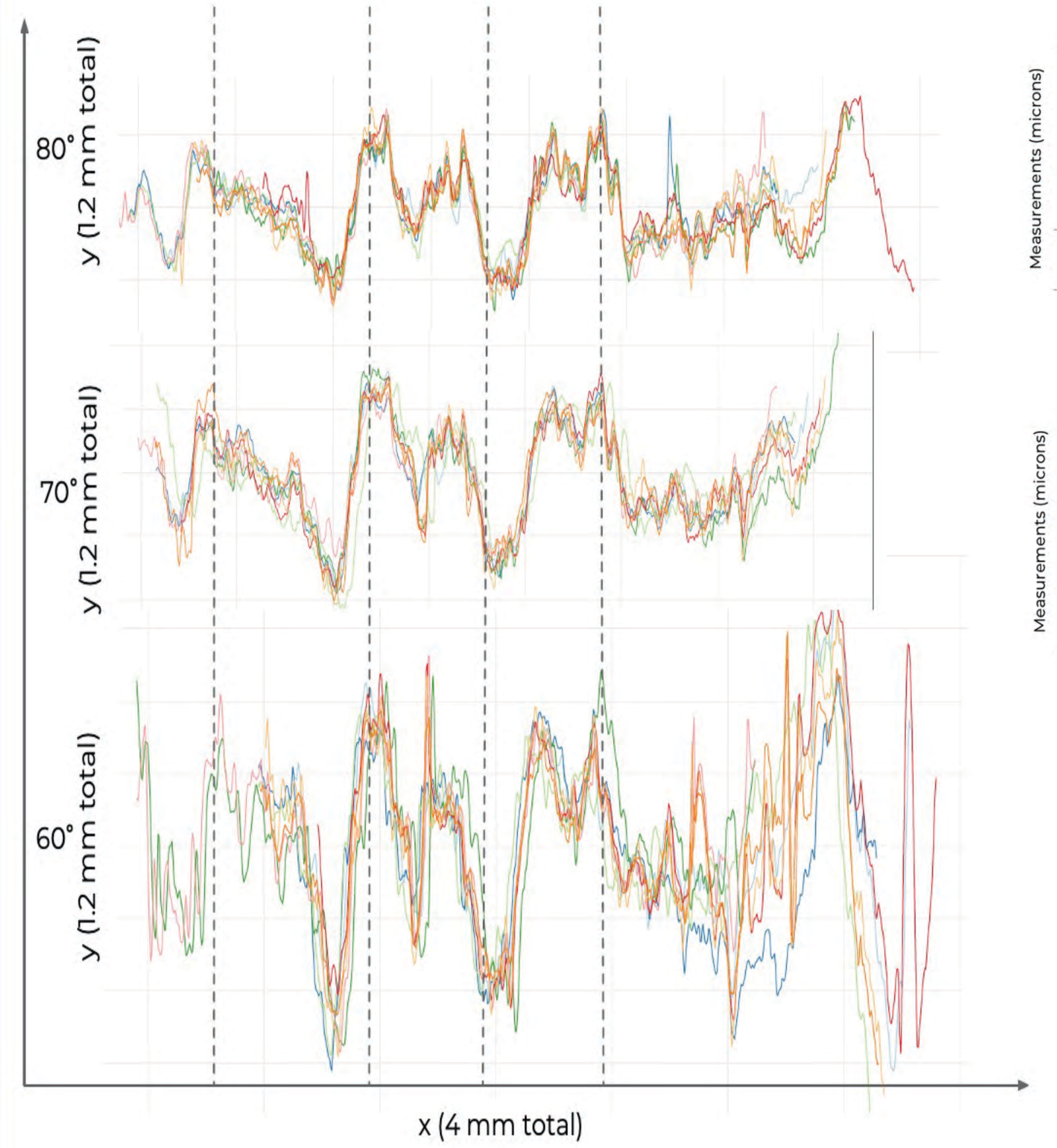

Figure 5: Angle comparison of superimposed signatures made from the same tool and side at 80 (top), 70 (middle), and 60 degrees (bottom).

Fig. 6 Direction Comparison

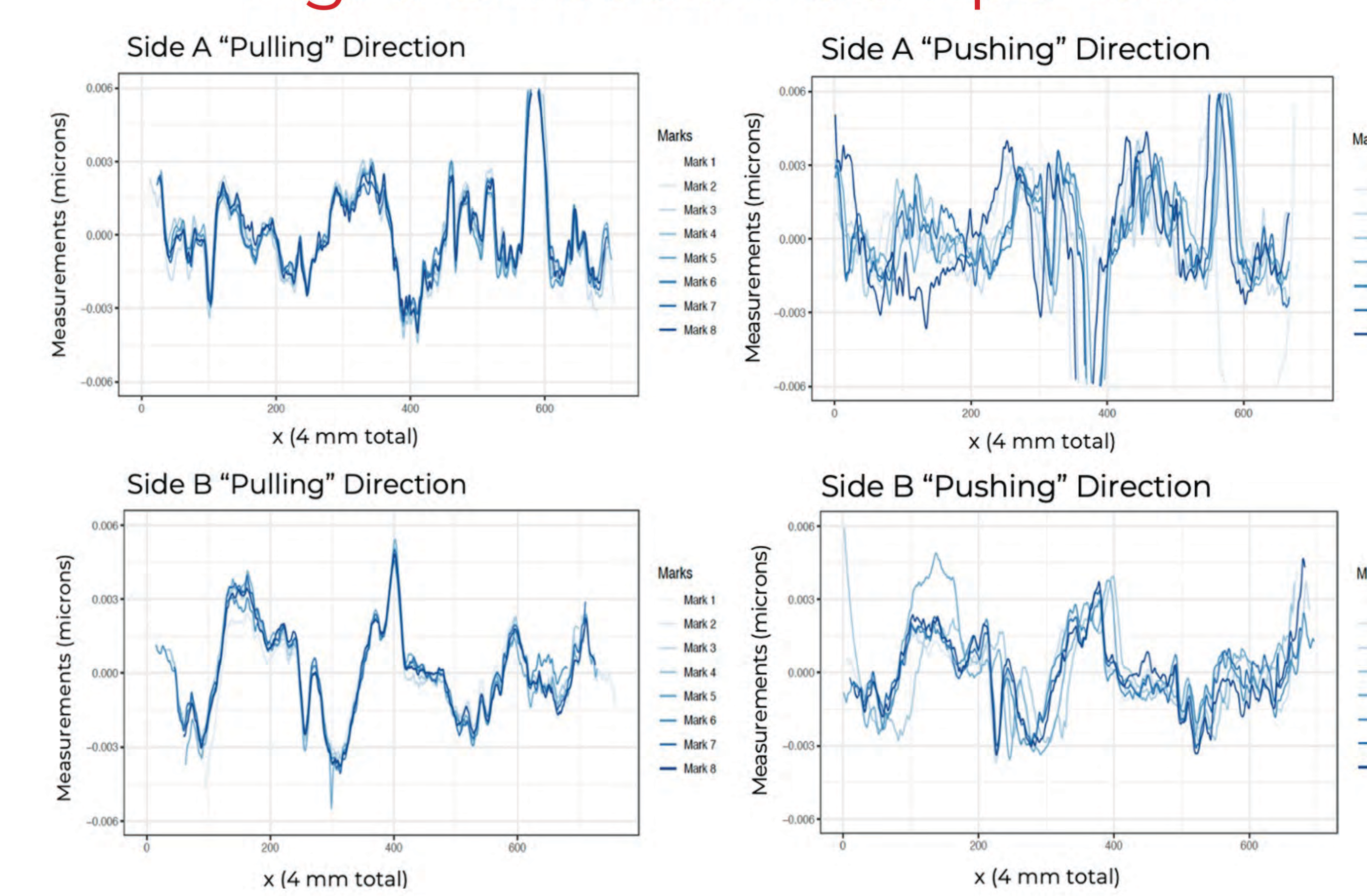

Figure 6: Direction comparison of superimposed marks from small screwdriver 1 side A going in the "pulling" direction (top left) and "pushing" direction (top right) compared to marks from side B going in the "pulling" direction (bottom left) and "pushing" direction (bottom right).

Fig. 7 Clustering Algorithm

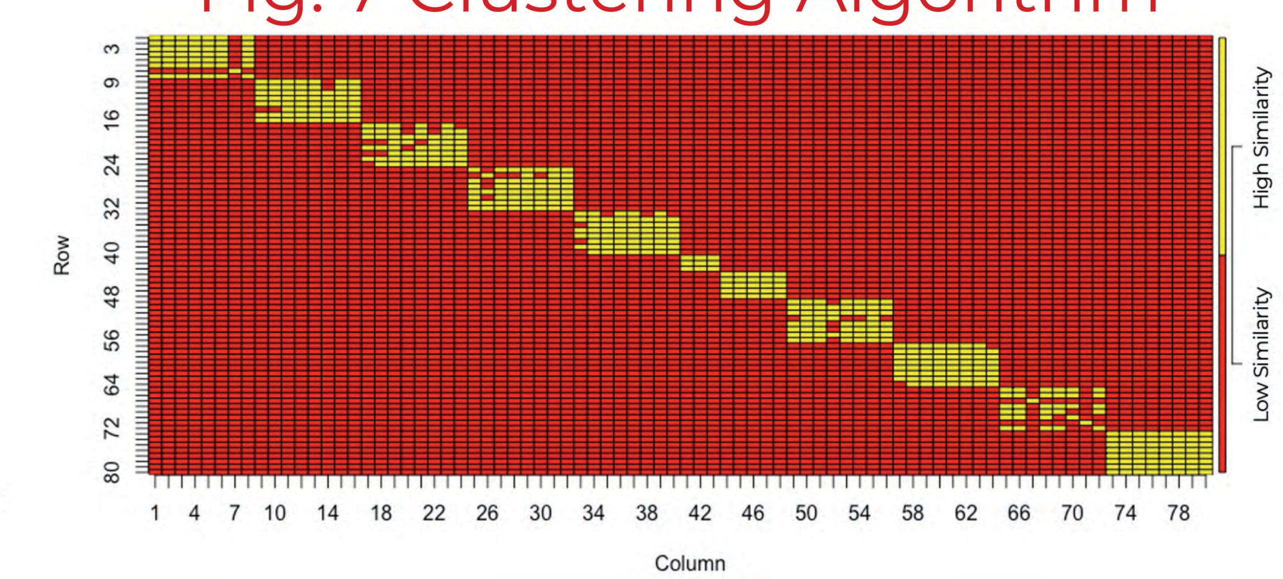

Figure 7: Results from clustering algorithm displaying cosine similarity between signatures from small, consecutively manufactured screwdrivers. The yellow clusters show marks made by the same tool and side, all made at 80 degrees.

4. Discussion

So far, we have 3D scans and their respective signatures from **over 600 toolmarks**. These toolmarks were made with the full set of 20 small, consecutively manufactured screwdrivers, and multiple large screwdrivers at 60, 70, and 80 degrees. There are similarities in the signatures of marks made from the same tool even at different angles. There is also variation between sides A and B of the same screwdriver and between screwdrivers.

5. Conclusion & Next Steps

Conclusion:
- Our toolmark lab is up and running. We are in the process of collecting more data and fitting the training data to the clustering and Bayesian algorithms. If we can model the variations within tool and by type of factor (e.g., direction, angle, etc.) across tools, then it may be possible to have as much success with bullets/cartridges.

Next Steps:
- Database – Generate more tool marks: This fall we will generate more toolmarks. We will add toolmarks made by the medium screwdriver set and add more toolmarks made in the "pushing" direction. We will also modify the rig to accommodate small screwdrivers at various angles and another degree of freedom- angle of rotation.
- Algorithm – So far so good, but we need more training data: The preliminary results from the algorithms are encouraging, but we need more data to see how they will perform in a more realistic setting. As we generate more data, the algorithm performance should improve.
- Validation – The next test: We will acquire toolmarks created by forensic laboratories for which the analysts know the right answer and we do not, so we can test the performance of our algorithm.

6. References

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This work was funded (or partially funded) by the Center for Statistics and Applications in Forensic Evidence (CSAFE) through Cooperative Agreements 70NANB15H176 and 70NANB20H019 between NIST and Iowa State University, which includes activities carried out at Carnegie Mellon University, Duke University, University of California Irvine, University of Virginia, West Virginia University, University of Pennsylvania, Swarthmore College and University of Nebraska, Lincoln.