Quantification of Toolmarks

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Outline

I. Introduction and Background

II. Experimental Results

   A. Initial Study

   B. AFTE Study

   C. Contextual Study

III. Summary and Conclusions

Introduction

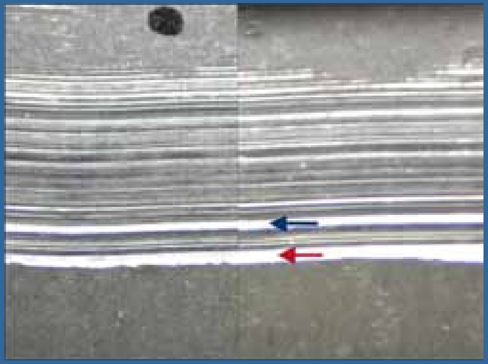
Iowa State University / Ames Laboratory has been conducting research on toolmark characterization for a number of years.

Experiments have involved toolmarks created using sequentially manufactured screwdriver tips. The goal is to provide scientific data either to support or disprove the basic assumption:

<u>The marks are unique to a single tool.</u>

Screwdriver tip used in study

Example comparisons of two toolmarks



Methodology

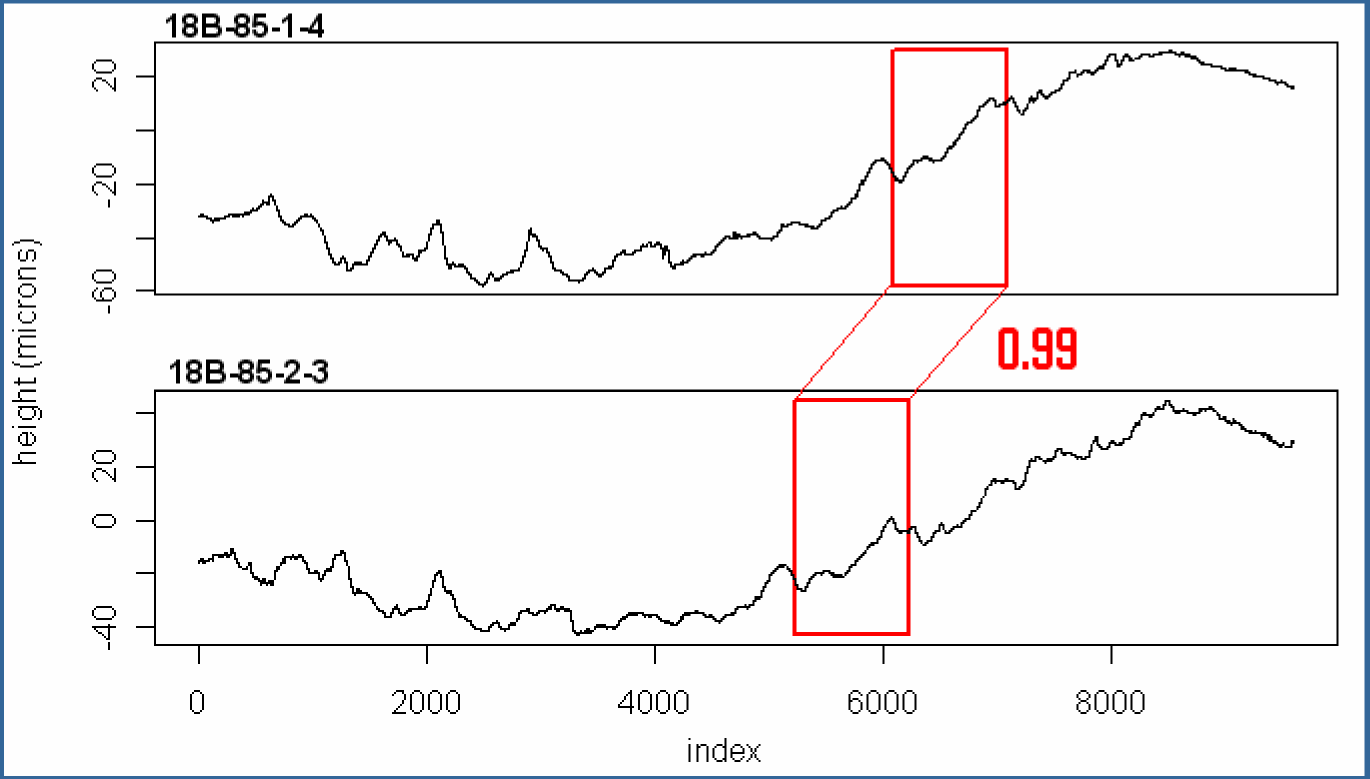
A computer-based search/match algorithm has been created that delivers a numerical number describing the quality of a comparison. The algorithm mimics a toolmark examiner in that it...

* Compares two data sets.
* Finds the region that has the best agreement.
* Provides a mathematical measure of the quality of that matched region when compared to a background value.

Operation

Visually, a similarity can be seen between the two data sets below.....

Profilometer data file - measures height as a function of linear distance.

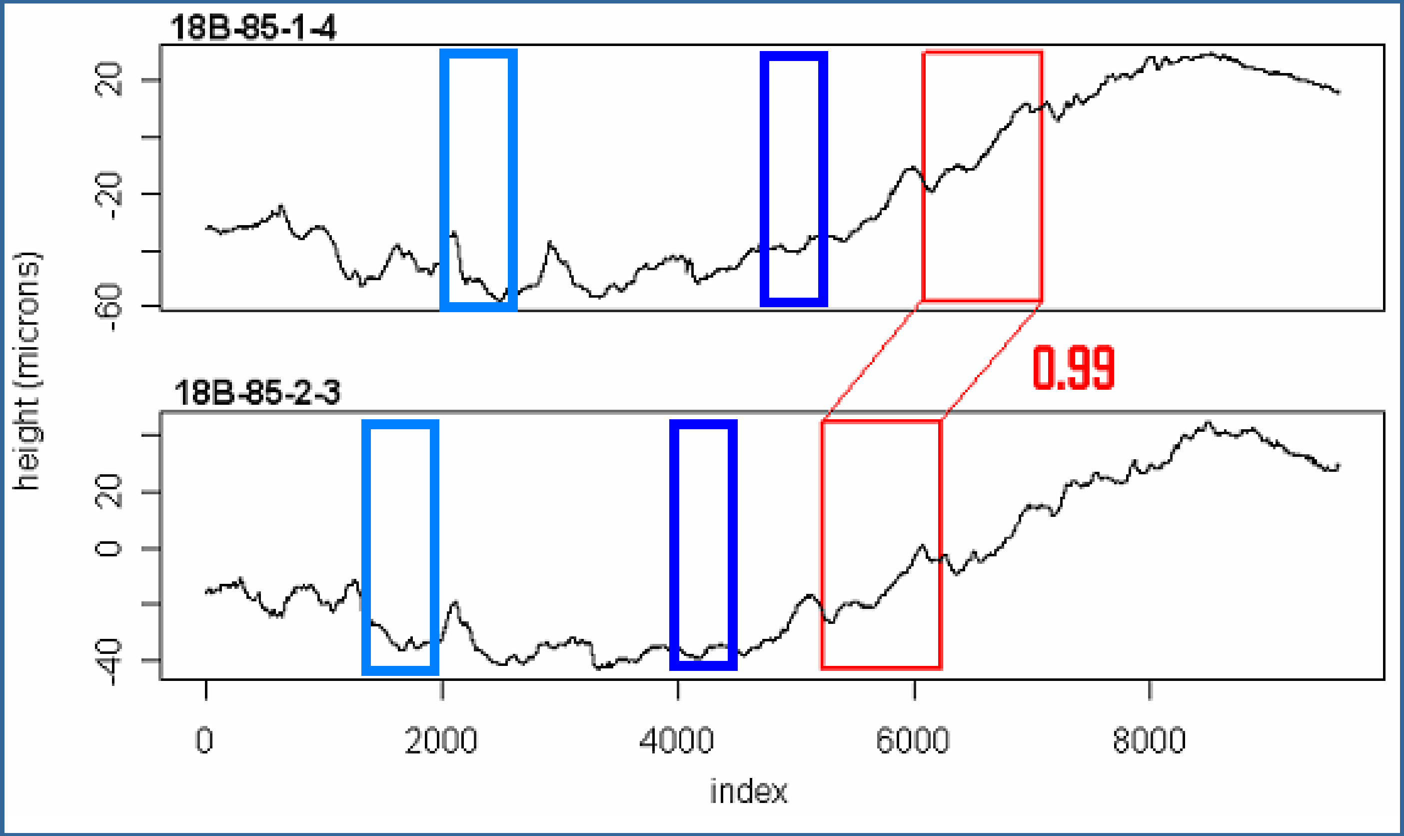


The algorithm compares small sections of the data sets and records the pair of windows with the highest correlation.

Verification

If a proposed match between two specimens is real, it will hold up outside the region of the proposed match:

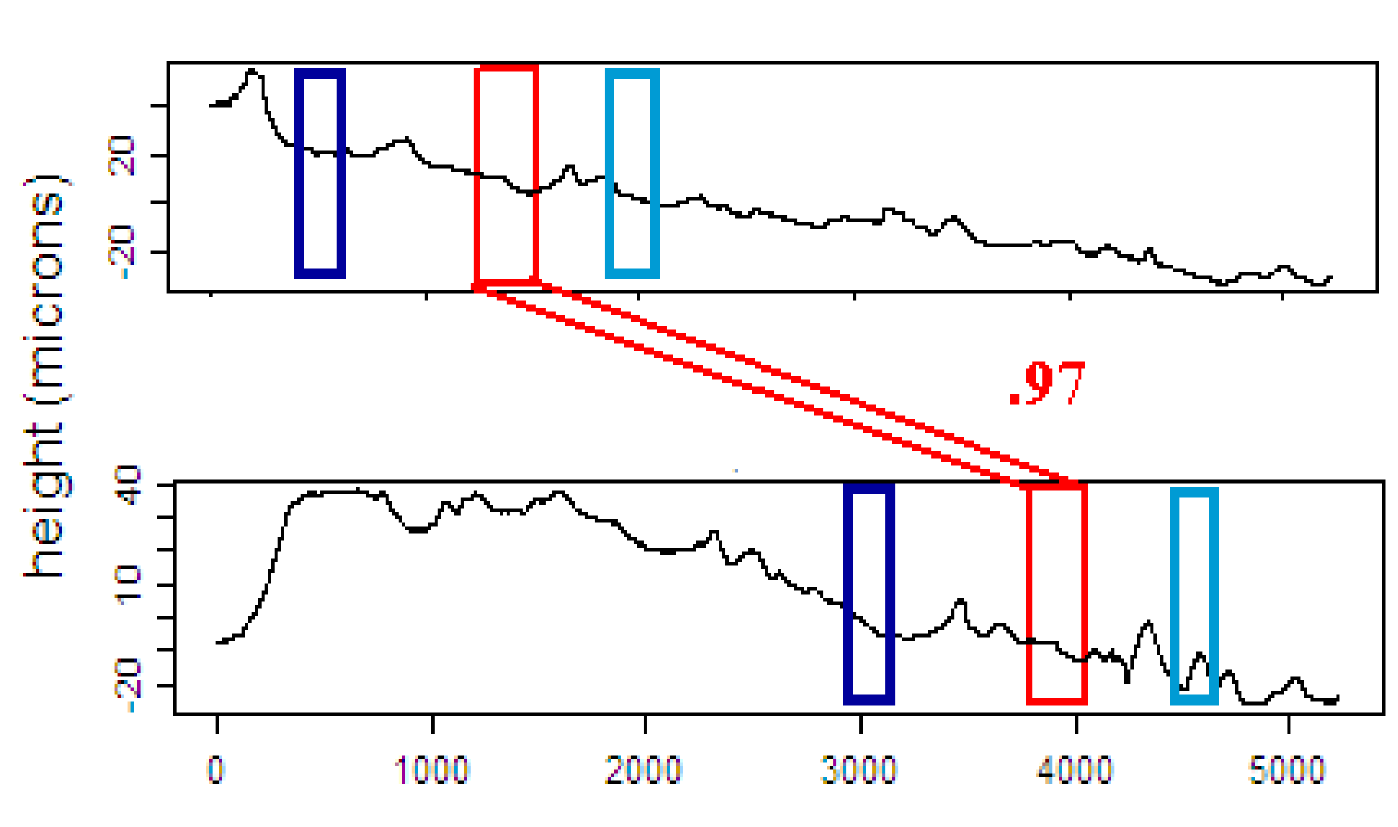
Red region denotes identified “match”. Blue regions show rigid translations to other possible comparison section.



Verification

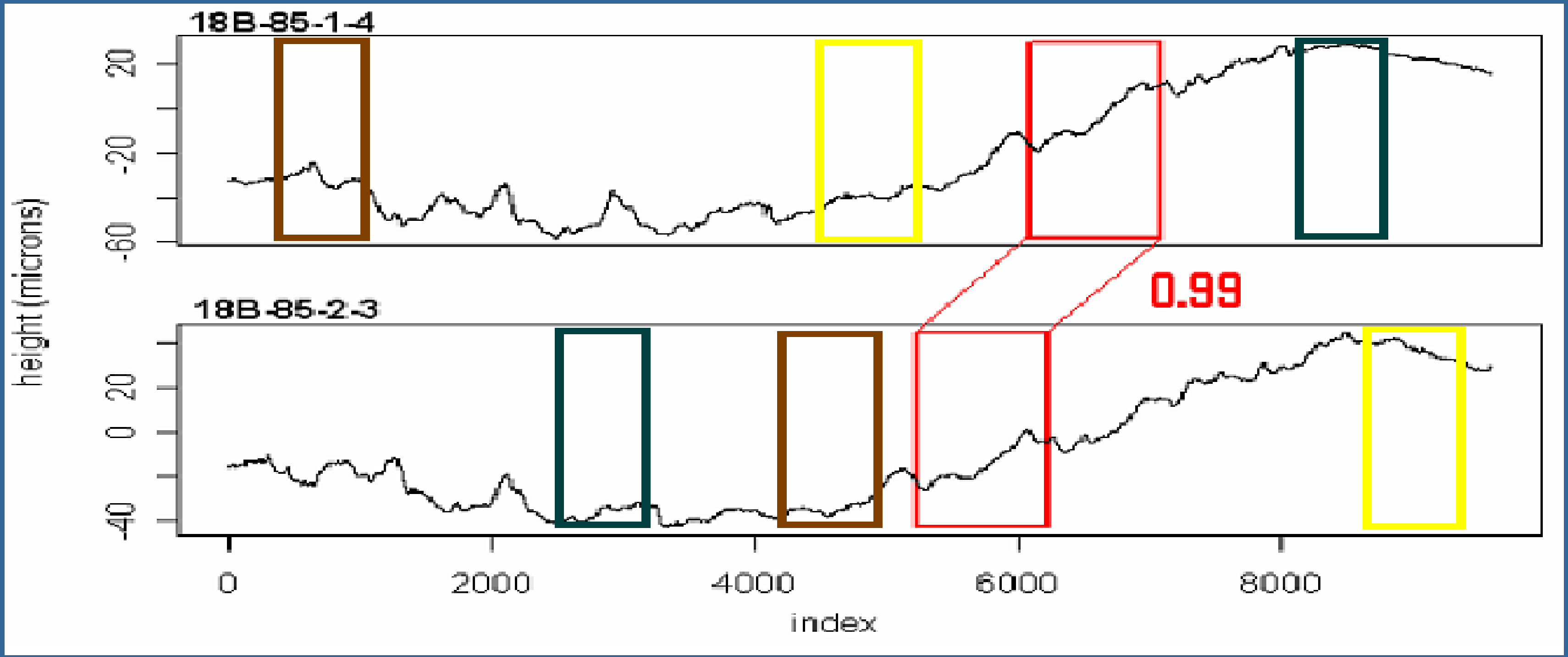
If the "match" is just coincidental, there is a low probability that a rigid translation will also match. In other words, the "match" will break down outside the initial region.

Red region denotes identified "match". Blue regions show rigid translations to other possible comparison sections.



Validation

For validation, the correlations of the verification step is compared to randomly chosen test segments.



This determines a reference background and calibrates the system so that you can obtain a numerical measure of the validity of a match.

Points to Remember

A “0” value for T1 means no relationship (or “match”) exists.

A nonzero value indicates the possibility of a match. The greater the T1 value, the more confidence a match exists.

What is important is separation between the data for matches and non-matches. The greater the separation, the higher the confidence of a correct result.

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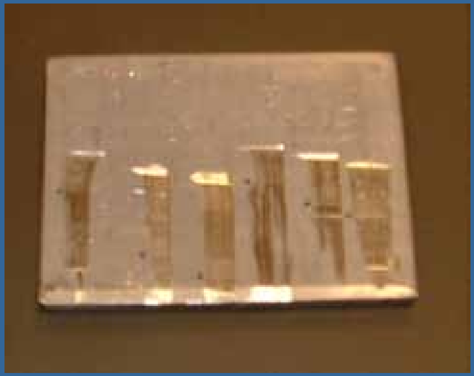
Sample Study

50 sequentially made screwdriver tips and their resultant toolmarks were examined using surface profilometry.

Screwdriver tip

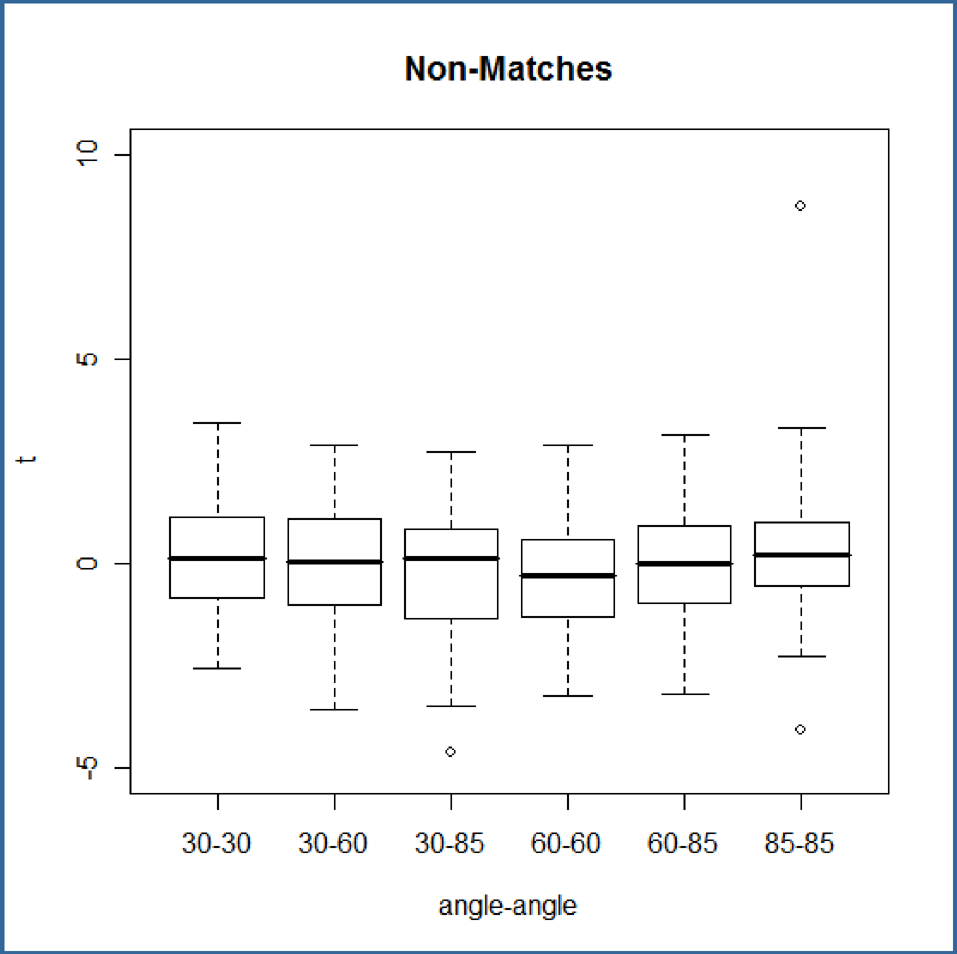


Toolmarks in lead.

* 4 Replicated marks are made at 30°, 60°, and 85°.
* 50 different tool tips used, 2 sides for each tip.
* 10 profile scans made on each mark.
* 4 x 3 x 50 x 2 x10 = 12,000 potential data files

Results

Hypothesis #1: Screwdrivers are unique; different screwdrivers leave different marks, no matter what the angle of comparison.

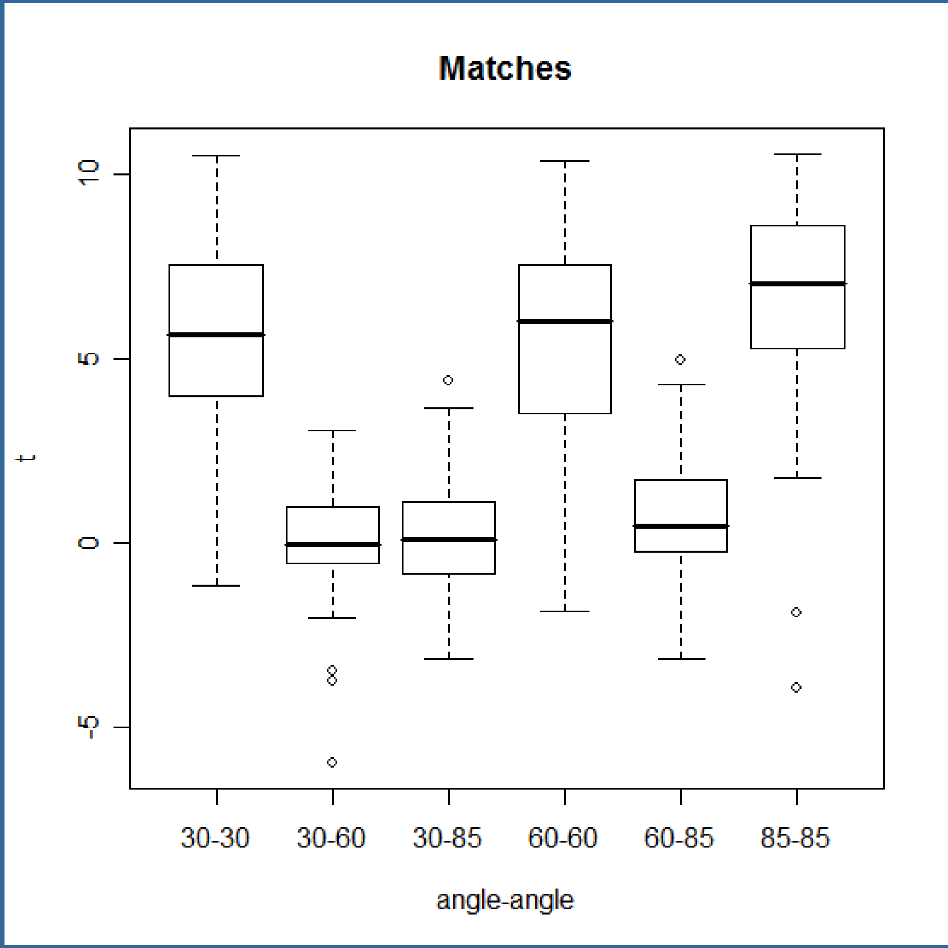


No relationship is seen above "background." Results support experiential knowledge of examiners.

N.B. A "0" value says no relationship exists above background. Boxes show where 75% of the data falls. Outliers marked.

Results

Hypothesis #2: When comparing marks made from the same tip and side, the comparisons must be made at similar angles to get a valid match.

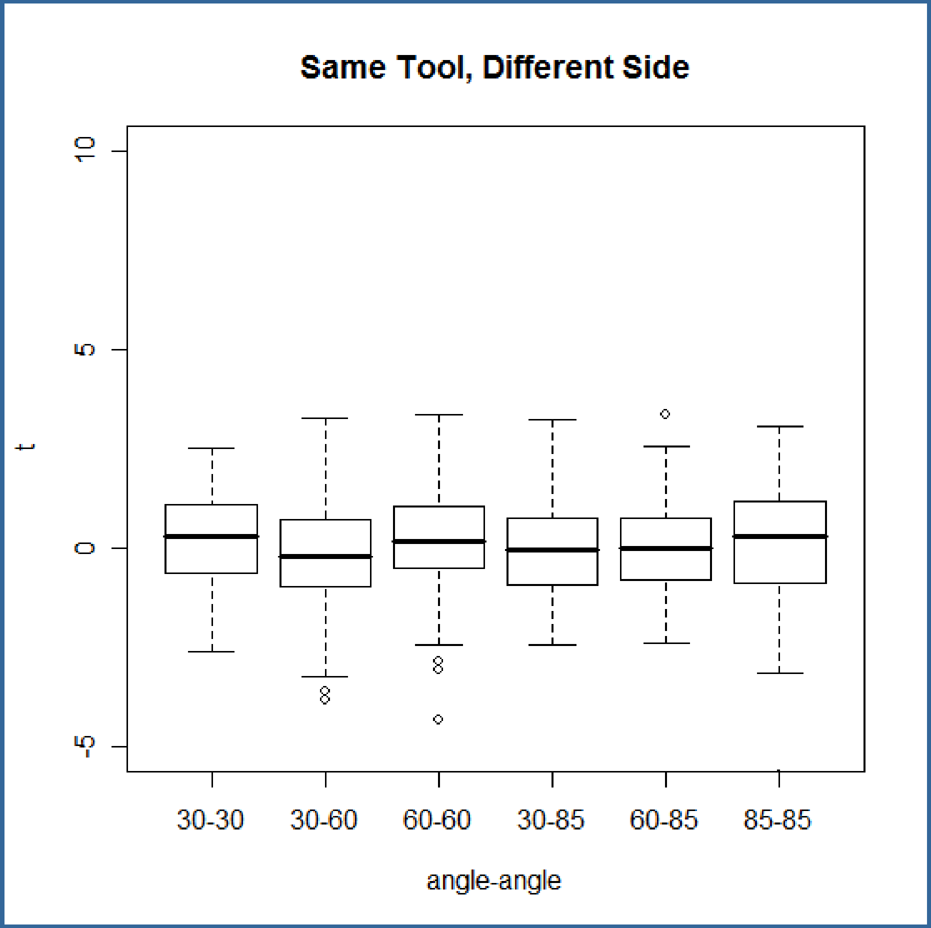


Results support experiential knowledge of examiners.

N.B. A “0” value says no relationship exists above background. Boxes show where 75% of the data falls. Outliers marked.

Results

Hypothesis #3: When comparing screwdrivers, marks made from different sides of the same tip appear as if they came from totally different screwdrivers.



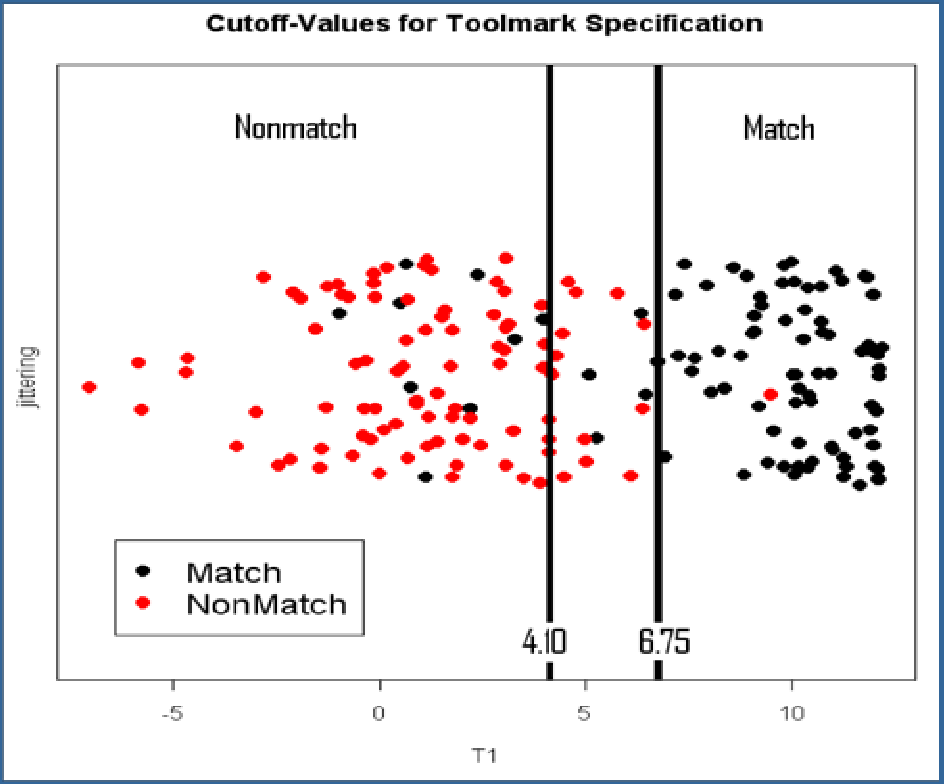
Results support experiential knowledge of examiners.

N.B. A "0" value says no relationship exists above background. Boxes show where 75% of the data falls. Outliers marked.

Analysis

Close examination of the data raises several questions....

A typical data set for comparisons made at 85 degree. Why did some nonmatches have high numbers? Matches have low numbers?



A study conducted at the 2008 AFTE conference tried to address these questions.

AFTE Study

Practicing examiners were asked to examine a range of samples (unknown to them):

Thanks to Don Gunnell and all the AFTE members!

5 Correct "matches"

5 Correct "nonmatches"

5 Incorrect "matches" (False negative)

5 Incorrect "nonmatches" (False positive)

Out of over 250 examinations no false positives were reported and only 12 false negatives. Analysis revealed that contextual information plays a large role in examiner methodology.

Contextual Study

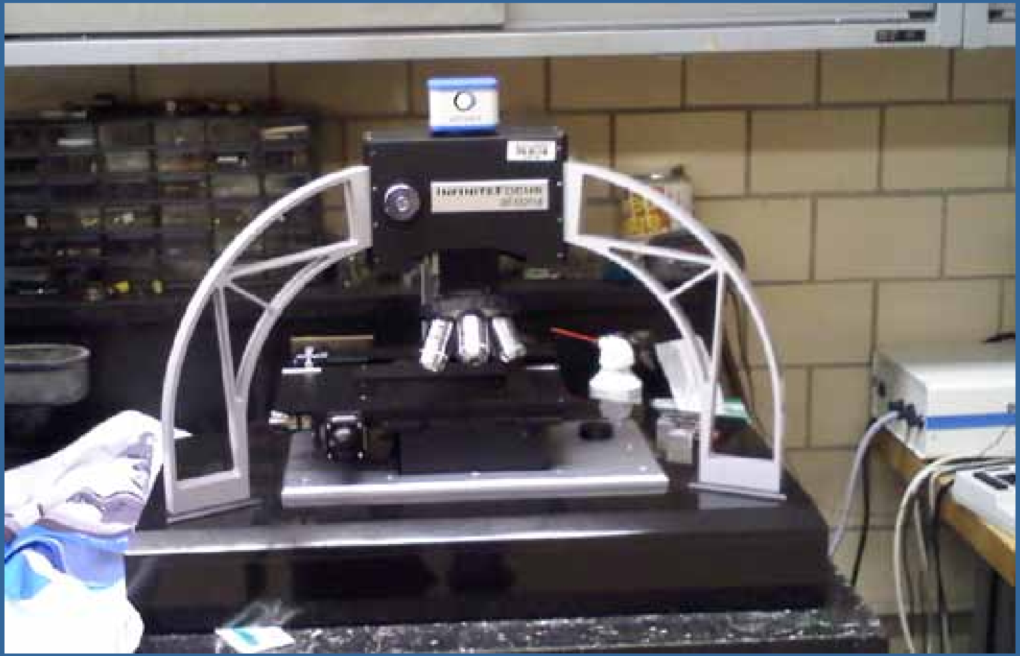
Data collection was repeated on the AFTE samples incorporating contextual information into the data analysis. This was aided by acquisition of a new instrument for data collection...

Alicona Infinite Focus Microscope (IFM).

Resolution: 800 nm at 5x, down to 10 nm at 100x

Extended x-y range of 100 mm by 76 mm at 5x

Measurement of steep angles up to 80 degrees



Additional advantage in that the sample surface is untouched.

Data Acquisition

How do you incorporate contextual information into data acquisition?

- IFM scans were acquired from regions where the sample mark was most complete.
- Care was taken to ensure edges were overlapped.
- Data from unmarked edges was minimized.
- Comparisons ensured left edge was aligned with left edge, right edge with right etc..

Results - "Match"

IFM and stylus results were similar for correctly identified matches, varied greatly for incorrect ones.

Correct "Matches": Optical data is at least as good if not better than stylus data.

Incorrect "Matches" (false negatives): Optical data with contextual information is MUCH better.

Contextual information results:

REDUCED FALSE NEGATIVES

Results - "Nonmatch"

IFM scans again were as good or better than stylus data.

Correct "Nonmatches": Optical data is at least as good if not better than stylus data.

Incorrect "Nonmatches" (false positives): Optical data with contextual information is MUCH better.

Contextual information results:

REDUCED FALSE POSATIVES

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Summary & Conclusions

Computer-aided analysis yields excellent results. Matches and non-matches can be identified in a quantitative manner.

Error Rates are low but not zero. The computer cannot always provide an unambiguous determination. Questionable comparisons must be examined.

Contextual information is critical for the best results. A person used to dealing with toolmarks should take the data.

Computer-aided analysis is objective. As such it has potential to reduce criticisms concerning impression evidence.

Other Projects

Several other projects are currently underway or planned at ISU / Ames Lab dealing with toolmarks.

Development of a “Virtual Tool” for toolmark characterization. Allow an examiner to know the exact angle, tilt, force etc. of impression evidence left by a screwdriver.

Face-Recognition Analysis of microstamped impressions. Allow micro-stamped cartridges cases to be read quickly.

Significance of Association in Toolmark Characterization. Refine the current algorithm to include better error analysis and extend analysis to cutting tools (pliers).

Development of Toolmark Database. Allow different evidence files to be compared quickly and easily.