Views on Statistical Statements in Forensic Testimony: Comments, Issues and the Role of Databases

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Focus of the Views Document

- Two major types of forensic evidence:
  - Those that involve comparison: DNA, toolmarks, fibers, fingerprints...
  - Those that involve an inverse analyses ("cause of an effect"'): blood spatter, time of death, shaken baby syndrome...
- Views document focuses on the first type: trace, pattern, DNA.
- Some statistical issues are common across types, not all.

Scientific underpinning of forensic practice

- Ideally, an expert's findings are supported by:
  1. A database that includes features of objects, images or other information and that is representative of the *relevant* population.
  2. A statistical model (or an alternative empirical approach) for the process that gave rise to the data or measurements.
  3. Information on variability and errors in measurements <u>and</u> in inferences derived from measurements ("analyses errors").
  4. A statement regarding the *weight of the evidence*: how rare is the observed association between two samples? ("Probability of a coincidental match"').

The state of the art

- Some forensic practices are solidly grounded in science. Example: single-donor DNA and simple mixtures.
- Other practices have made progress in that direction:
  - Glass (and other trace): excellent measurement processes, plausible statistical models. But limited (relevant) data, questionable error rates, impossible to evaluate weight of evidence.
  - Fingerprints: general agreement on what should be measured, some demonstrated reliability and repeatability among examiners. But, no large image databases available.
  - Firearms: as practiced, no scientific validity, but new 3D-surface topography methods promise to provide good measurements of striae. Statistical and machine learning methods under development. Limited data and no estimates of probability of coincidental match.
- For other practices: e.g., shoeprints, we do not even know what might be discriminating features.

What to report?

- Given the uneven state of the sciences, it is important that expert reporting (and testimony?) on forensic analyses include the following information:
  - The analytical (or subjective) approaches for obtaining the measurements or data from crime scene and from defendant, including potential sources of observation error.
  - The assumed statistical model (if any) or approach for computing similarity scores.
  - The data used to estimate model parameters or similarity scores.
  - The degree of association between two samples.
  - The probability of observing a similar degree of association between two samples which do not have a common source.
- The examiner should be required to explicitly state that s/he **does not know**, when any of the above elements is missing.

Of note:

- A forensic expert should not be allowed to state that two samples are indistinguishable (or share features, or...) without also:
  - Stating and documenting whether the degree of association is rare, **OR**
  - Stating that s/he does not know whether the degree of association is rare.
- Training and experience are *not substitutes* for properly conducted scientific studies:
  - In case work, examiners do not have ground truth, so unless challenged, they cannot know their own error rates.
  - Even the best examiners cannot evaluate the meaning of an association without reliance on relevant databases.

The importance of databases

- Three major uses of databases by forensic scientists:
  - Development of new analytical methods
  - Validation of methods
  - "Casework"
- Data appropriate for development of methods and "reference databases" need not share same attributes.
- Data for research *at a minimum* must permit estimation of model parameters or of distribution of similarity scores.

Glass as an example

- Until recently, most glass databases were not accessible by the general scientific community.
- Peter Weiss (BKA) shared some of their data.
- These data were used to develop a match criterion considered (at the moment) the state-of-the-art.
- An additional database with much the same structure collected by FIU was recently released to us as well.

Can we estimate all covariances?

- Elemental concentrations are correlated.

Table 16: Correlation matrix Withi

Li7	Na23	Mg25	Al27	K39	Ca42	Ti49	Mn55	Fe57
1.00	0.74	0.06	0.28	0.77	-0.00	0.18	0.48	0.52
0.74	1.00	0.02	0.15	0.77	0.02	0.10	0.07	0.46
0.06	0.02	1.00	0.87	0.06	0.96	0.93	0.32	0.25
0.28	0.15	0.87	1.00	0.31	0.88	0.94	0.51	0.29
0.77	0.77	0.06	0.31	1.00	0.05	0.19	0.25	0.41
-0.00	0.02	0.96	0.88	0.05	1.00	0.94	0.25	0.18
0.18	0.10	0.93	0.94	0.19	0.94	1.00	0.52	0.19
0.48	0.07	0.32	0.51	0.25	0.25	0.52	1.00	0.15
0.52	0.46	0.25	0.29	0.41	0.18	0.19	0.15	1.00
0.79	0.71	-0.02	0.28	0.80	0.03	0.21	0.49	0.29
0.14	0.07	0.94	0.92	0.17	0.96	0.96	0.44	0.22
0.11	0.16	0.92	0.84	0.13	0.95	0.93	0.25	0.23
0.34	0.07	0.68	0.75	0.25	0.64	0.78	0.83	0.21

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Data do not support plausible analyses

- The state-of-the-art approach is carried out element-wise.
- Assumption is that all elemental concentrations are uncorrelated, clearly not a correct assumption.
- We are in the process of conducting a large simulation study (since there are no real data available!) to show the effect of ignoring correlations on the sensitivity and specificity of:
  - Approach proposed by glass experts
  - An alternative approach based on distances between pairs of known matches and known non-matches.
- Latter approach proposed by Carriquiry, Michaels and Stern (2004) in the context of elemental composition of bullet lead – an **identical problem** from a statistical point of view.

To finalize...

- CSAFE is an umbrella organization that today includes two centers:
    - The NIST Center of Excellence in Forensic Sciences
    - The Midwest Forensics Resource Center (MFRC)

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Center for Statistics and Applications in Forensic Evidence

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THANKS!

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