CRIME LAB REPORT
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Stochastics – The real science behind forensic pattern identification

November 24, 2009 by John M. Collins, Chief Managing Editor of Crime Lab Report and Director of the DuPage County Crime Laboratory in Wheaton, IL

It is the science in which all of forensic science will grow newer and deeper roots.

It is a mathematical foundation for common forensic testing methods that never before could be quantified in understandable terms.

It provides, without a doubt, a statistical and philosophical framework that can drive revolutionary research in all of the forensic sciences, including DNA.

It is called *Stochastics – the science of randomness*. Many forensic scientists have never heard of it. But it waits with open arms to welcome a profession that is in desperate need of a home.

For over a century, many of the classical forensic disciplines such as latent prints, toolmarks, and footwear impressions have struggled to overcome a debilitating identity crisis. Practitioners in these disciplines rightly insist that their work is rooted in good science. But when scrutinized by persistent inquisitors who expect conclusions of uniqueness to be accompanied by a quantitative assessment, many forensic scientists are left to simply present their "training and experience" as the ultimate foundation upon which their conclusions rest.

Undoubtedly, a forensic scientist's training and experience are critical and relevant. We also know that accurate and reliable forensic determinations are being made each day even though mathematical formulas don't yet exist to back them up. But it is not enough to *make* forensic science determinations. They must be *communicated* as well.

That's where the problem lies.

In today's scientific and legal environments, presenting one's training and experience as the exclusive, underlying foundation of critically important conclusions, particularly statements of certainty and uniqueness, is no longer seen as appropriate and never will be again. No matter how forensic science practitioners feel about this trend, many current practices must eventually give way to something more transparent and perceptibly objective – both for scientific reasons and to command a higher level of confidence, which is actually what science is about anyway.

That time may not have come just yet, but it will. So if the forensic science community is to be seen as trustworthy, responsible, and truly desirous of continual advancement, it must actively support and encourage the newer kinds of research that will allow scientists to communicate their results more effectively.

It seems that within the realm of stochastics all of the nuances and complexities of forensic science, which so often frustrate judges and lawyers, make complete sense. Here's why.

Take something as seemingly simple as the flip of a coin. Despite all of the scientific and mathematical knowledge at our disposal – knowledge that has found cures to the most devastating diseases and has safely landed astronauts on the moon – there is no way to predict with any degree of mathematical certainty on which side a well-flipped coin will land.

Yes, we can calculate the odds that the coin will land with heads or tails up. But we cannot conclusively predict it.

In other words, the flip of a coin is not so simple after all. The random processes that result in one side facing upwards are infinitely complex and therefore escape our predictive reach.

Calculating the odds that a coin will land either heads up or tails up is a *deterministic* problem. Predicting exactly which event will occur is a *stochastic* problem.

In the pattern identification disciplines, the words deterministic and stochastic are generally not used. The terms *class* and *individual* are used instead but they mean the same thing. In DNA testing, stochastic phenomena are dealt with on a regular basis and are described as such. Random appearances and disappearances of genetic alleles occur unpredictably during the analysis of extremely low levels of DNA and can't be mathematically explained.

In reality, stochastic problems and processes are everywhere and are relevant to the most complex issues in the human experience. Forensic evidence is no exception and the absence of exact mathematical models to describe what many practitioners observe in a forensic testing laboratory does not, and should not, minimize its scientific standing.

Doctors, for example, cannot predict the exact number of days that a terminally ill patient will survive after his or her diagnosis. The outcome is dependent upon stochastic processes.

Behavioral psychologists cannot predict the chance that a child will grow up to become a serial killer. The outcome is dependent upon stochastic processes.

Geophysicists cannot reliably predict the chance that an active volcano will erupt in the next year. The outcome is dependent upon stochastic processes.

The natural world is dominated by random variations and infinite possibilities, a problem that cursed even the great Albert Einstein who believed that mathematical equations could ultimately explain and predict everything.

"God does not play dice with the universe," he once wrote to a friend.

"But God does play poker," warned the famous physicist Stephen Hawking.

The patterns observed in latent fingerprints, on bullets, in a person's handwriting or on the bottom surface of their shoes are also the results of stochastic processes that cannot be controlled. Patterns that result from these processes are judged to be unique mainly because decades of observation and research have only validated the formulation of such judgments.

But there is one small problem.

Those who conduct comparisons of stochastic patterns in forensic science know very well that there are limits to their ability to assess uniqueness. With enough smudging or interference, a latent fingerprint cannot be identified to the person who deposited it. With enough damage, a bullet cannot be identified to the gun that fired it.

Not all identifications are created equally. Some are easy. Some are difficult. In the most extreme instances, comparisons can result in identifications with which not all examiners would agree.

It is precisely these extreme instances – the gray areas in forensic science – that require attention. It is also the reason that identifications, or conclusive statements of origin, demand the highest levels of scientific justification.

Make no mistake, forensic practitioners present authoritative and reliable opinions about the identity and origin of latent prints, toolmarks, footwear impressions, and other stochastic pattern evidence. But as questions begin to explore a practitioner's opinion about *all other* sources, *other* people, *other* guns, and *other* shoes, a more conservative and cautious approach is now expected until the research justifies "the exclusion of all others."

In the meantime, a more responsible and perhaps a more compelling approach is for forensic scientists to simply state the truth about identifications. "I have never seen, nor would I expect to see, this amount of similarity in [friction ridge patterns, bullet striations, footwear impressions, or other types of pattern evidence] that came from different sources."

This is a statement of fact and *is* supported by the practitioner's education, training, and experience. Arguing, on the other hand, that an identification excludes every possible source that ever did, does, or could exist is probably correct, but it cannot be entirely defended under the scientific expectations that our courts now have. And when identifications fall increasingly close to those marginal gray areas, the risks naturally increase.

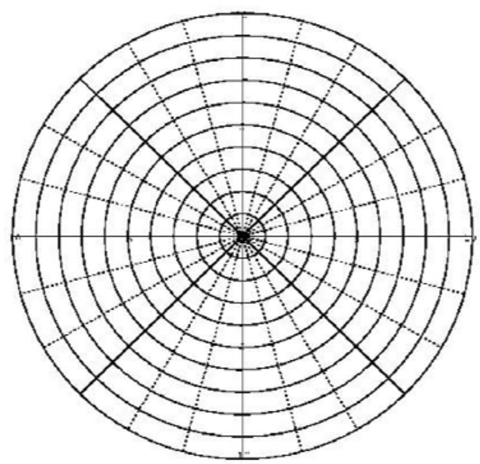
So how are the courts to know if an identification falls close to or far from these margins of higher risk? Where *are* the margins? How much *is* enough? Judges and juries have a right to know.

To get a glimpse of where future research can take the profession, the following questions are posed.

Would you believe that the odds of two different guns leaving the same pattern on the primer of a cartridge case (the small metal disc that ignites the gun powder when struck by the gun's firing pin) were less than 1 in 60.5 sextillion? Would a judge or jury find this information to be compelling if there was ample research to support the claim?

Consider the following example.

Imagine a circle. Now imagine dividing this circle into 360 equally spaced radial-lines (spokes), and 100 equally spaced concentric circles (percent of the radius).



If you count every location where lines intersect, you wind up with 36,001 "points" of comparison.

Using this rough model, one can quickly see how easy it is for nature to create unique stochastic patterns that can be evaluated by forensic scientists.

If two different people drew one of these hypothetical circle-grids then randomly and independently selected five of the 36,001 available points, the odds of them selecting the same pattern of points is as follows:

Selecting one identical point = 1 in 36,001

Selecting two identical points = 1 in 1.3 billion

Selecting three identical points = 1 in 47 trillion

Selecting four identical points = 1 in 1.6 quintillion

Selecting five identical points = 1 in 60.5 sextillion

The real-life patterns observed by forensic scientists are even more complex and varied; therefore, the subsequent statistical expressions of uniqueness will likely be even more impressive, and possibly more mathematically definitive, than DNA.

We just need the research to show it.

We can never know the <u>exact</u> chance that two different persons will leave the same fingerprint pattern, or that two guns will impart the same pattern of striae on the surface of a bullet. The randomness of the stochastic processes involved simply will not allow it. Perhaps this is one reason why statistical research in the pattern identification disciplines was never funded or prioritized with any enthusiasm.

But research can, in fact, quantify the margins and establish useful thresholds to help practitioners explain the significance of their observations. This will be a huge achievement.

Coincidently, Taylor and Francis, the same organization that publishes the new journal *Forensic Science Policy and Management*, also publishes *Stochastics – an International Journal of Probability and Stochastic Processes*.

Dr. Elart Von Collani at the University of Wurzburg in Germany has become a leading expert in the stochastic sciences. In 1995, he published an article in the *European Journal of Engineering* that seemed to provide a reasonable explanation for one of the problems observed by the National Academy of Sciences in its 2009 report, *Strengthening Forensic Science in the United States – A Path Forward*.

The NAS report complained that "the forensic science enterprise is hindered by its extreme disaggregation—marked by multiple types of practitioners with different levels of education and training and different professional cultures and standards for performance and a reliance on apprentice-type training and a guild-like structure of disciplines, which work against the goal of a single forensic science profession."

But according to Von Collani, this type of fragmentation is to be expected. "Each field of traditional science creates its own stochastical branch," he explained, "thus preventing unification."

In other words, fragmentation exists in the forensic sciences precisely because each segment of the profession is dealing with its very own specialized stochastical branch. The details and minutia observed by a latent print examiner is of no relevance to a toolmark examiner.

Admittedly, Von Collani was not writing about forensic science specifically. But there are strong parallels and common ties that bind all of the stochastic pattern disciplines. It will take some time for forensic practitioners to become fully aware of them. In the meantime, the right research conducted by the right people can liberate many embattled forensic disciplines and empower their practitioners to report conclusions with more scientific certainty.

One way for this transformation to begin is for forensic scientists and researchers in academia to think differently about stochastic patterns.

A striation on the surface of a bullet, for example, is not just a scratch. Nor is the bifurcation of a friction ridge in a fingerprint pattern simply a second-level detail.

Instead, both the bullet striation and the friction ridge bifurcation are *events*. And like all events, they have a certain probability of occurring.

It will take some time for forensic scientists to stop thinking of patterns as a collection of *characteristics*. But sooner than later, they must begin to evaluate these patterns as a collection of events. Only then can they further elevate their respective forensic disciplines to the new heights of scientific credibility that are now expected.

The forensic pattern identification disciplines are, and have been, reliable and valid. It's the expectations that have changed. For this reason, research must be designed and executed to help us meet this new challenge.

This new opportunity to enhance what is done in the future must not be construed as an indictment of what was done in the past.

Anyone with scientific sense knows the difference between the two. *****