New algorithm examines crime-scene bullets segment by segment

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On the morning of March 22, 1915, residents of the small town of West Shelby, New York, awoke to a horrific scene. A woman clad only in a bloodied nightgown lay shot to death in the snow on the doorstep of an immigrant farmhand, Charles Stielow. Across the street, in the farmhouse where Stielow had recently begun work and where the dead woman had kept house, 70-year-old farmer Charles Phelps was found shot and unconscious. He died a few hours later.

After finding that Stielow lied when he told investigators he did not own a gun, the police arrested him on Aug. 21, 1915. During Stielow's trial, a self-proclaimed criminologist, Albert Hamilton, testified that the nine bumps he said he found inside the barrel of Stielow's .22 caliber revolver matched the nine scratch marks he had identified on the same caliber bullets at the crime scene. Although Hamilton never showed his evidence to the jury, declaring the findings were so technical they could only be discerned by an expert, Stielow was found guilty of murder in the first degree. He was sentenced to death in the electric chair and sent to Sing Sing prison to await execution.

Several people familiar with the case, including the deputy warden at Sing Sing, became convinced that Stielow was innocent and that his confession contained words that the farmhand, who was mentally challenged, could not have understood let alone uttered. Just one week before Stielow was scheduled to be electrocuted on December 11, 1916, the Governor of New York called for a reinvestigation. A firearms expert from the New York City police department compared the bullets from the murder scene with those test-fired from Stielow's gun. Even by eye, the markings on the two sets of bullets did not look similar but to make certain, optician Max Poser studied them under the microscope. The bullets from the murder scene could not have been fired from Stielow's gun, he declared.

Poser's analysis not only set Stielow free, it made history as one of the first examples of applying modern forensic techniques to identify firearms.

Today, forensic scientists still use a type of microscope, developed and perfected by two of Poser's colleagues in the 1920s, to examine crime-scene bullets or cartridge cases—the metal cylinders that hold the powder and bullets before they are fired. Known as a comparison microscope, the device consists of two microscopes connected by an optical bridge.

The microscope's split screen allows for a side-by-side comparison of the miniscule scratch marks, or striations, on bullets or cartridge cases found at the crime scene with the markings on bullets or cases test fired from a particular gun. These striations are imparted on bullets as they squeeze through the spiral windings, called rifling, down a gun barrel at high speed and pressure.

The firearms examiner adjusts the position of the test-fired bullet until its striations best match those on the crime-scene bullet. In this way, the examiner can provide her expert opinion about whether the crime-scene bullets came from the same gun that was test fired.

The method is highly successful, but the comparison results are subjective, dependent on the expertise of the examiner. The visual comparison does not allow the firearms expert to objectively quantify the level of uncertainty in the comparison. For example, what is the likelihood of obtaining the comparison result if the bullets in fact came from the same firearm or from different firearms? Courts now prefer such statistical information, which is, for example, routinely provided by DNA experts when they testify about genetic evidence.

Last year, NIST scientists premiered a computer-based comparison method that can provide this numerical information. The algorithm, known as congruent matching profile segments (CMPS), relies on detailed 3-D maps.

"Firearm experts are actually quite good at making comparisons, so it's not a question of replacing human judgement with a computer algorithm," noted NIST scientist Robert Thompson, a member of the NIST team. "The algorithm provides a way to mathematically rate the reliability of the expert's findings."

Crucially, instead of comparing the overall map, or profile, of one bullet to another, the algorithm first divides the profile of each crime-scene bullet into tiny, non-overlapping segments. Then, it looks to see if any of the individual segments match up with any section of a test-fired bullet.

The segmentation is an important feature because crime-scene bullets usually deform or fragment after ricocheting off a solid surface or rapidly decelerating in the human body. As a consequence, rifling striations may be erased, expanded or shifted in position. Comparing the entire profile of such a deformed bullet with the pristine markings of a bullet test-fired into a water tank may indicate a low probability of a match—even though the bullets may have been shot by the same gun. Searching for matching features segment-by-segment provides a much more accurate way of comparing crime-scene and test bullets.

Before the team applied their comparison method, the researchers used image reconstruction techniques to "straighten out" and display as parallel scratch marks that had become distorted or slanted as the bullets deformed. But even after the markings on the crime-scene bullets are straightened, they may not line up with the position of similar markings on the test bullets. That's where CMPS comes in, says PML scientist Johannes Soons. The algorithm takes a small section of the markings on the deformed bullet and hunts for any place on the test bullets that may prove a match. The software then evaluates how many segments were found at a correct position relative to the markings on the test-fired bullet. The method builds upon an older algorithm, developed by PML scientist John Song, that compares impressed firearm marks on cartridge cases.

In the initial study that the NIST-led team reported last December in Forensic Science International, the scientists only used the CMPS method to compare non-deformed bullets fired from known guns. The team shot 35 9-mm Luger bullets into a water tank from 10 gun barrels that had consecutively manufactured.

Each barrel in the study imprinted scratch marks on the bullets. The researchers found that CMPS more accurately determined the origin of each bullet than a comparison method that did not divide the bullet markings into segments.

In the team's newest study, published in the January Forensic Science International, the researchers for the first time employed the CMPS method to examine deformed bullets. The team fired 57 bullets with varying degrees of fragmentation from the same 9 mm pistol into a water tank. To create bullet fragments with varying degrees of deformation, the researchers aimed the gun at a slight angle, so that the bullets struck the sides of a heavy gauge steel tube placed in front of the water tank instead of shooting straight into the water.

The team conducted two kinds of tests using the image reconstruction software and the CMPS algorithm. The researchers compared severely distorted markings on bullets with those imprinted on near-pristine reference bullets shot directly into the water tank. They also compared deformed bullets before and after image reconstruction that straightened the distorted markings. The scientists found that together, image reconstruction and CMPS significantly improved the ability to match the markings on deformed bullets with each other and with the pristine bullets.

The team is now planning to conduct further studies to test the CMPS method. With the freedom—and perhaps the life—of a defendant hanging in the balance, these studies are critical for determining if—and when—CMPS can be routinely incorporated into the analysis and testimony of firearm experts, says Soons.

More information: Zhe Chen et al. Pilot study on deformed bullet correlation, *Forensic Science International* (2019). DOI: 10.1016/j.forsciint.2019.110098

Zhe Chen et al. Fired bullet signature correlation using the Congruent Matching Profile Segments (CMPS) method, *Forensic Science International* (2019). DOI: 10.1016/j.forsciint.2019.109964

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