Integrating forensic science: physics-based

Introduction For the past two decades or so, television shows, books, and movies that portray detective work and forensic science have become increasingly popular among readers and enthusiasts. They demonstrate that science is an important tool in answering difficult questions regarding how the tragic assassination of President Kennedy happened for example. Forensic Science is appealing to many people because they want to be detectives to solve problems and puzzles.

Today I will focus on how scientific principles embody the study of forensic science but with a main focus on how physicists and crime scene investigators use physics, among other sciences, to solve crime cases in forensics. Forensic Science is a multidisciplinary that embodies concepts in many areas including but not limited to biology, chemistry, anatomy, genetics, physics, and math. Forensic Science appeals to the natural detective in some people and also to those who like to solve complex puzzles. The ultimate goal is to make sense out of complex problems that require reasoning and involve numerical data, evidence, and uncertainty.

Many areas are studied in Forensic Science for example fibers are primarily chemistry-based while other sciences are required for characterization of evidence as well as assessment of its forensic value. Other principles are shared among math, biology, and physics. Statistics, in this case, is used to access the probability of a fiber linked between suspect and victim (math) as well as microscopic observation used to differentiate natural and synthetic fibers (chemistry). Also since fibers are pieces of evidence that can be found at a crime scene; the presence of fibers may be considered trace evidence.

Most trace evidence is not unique to an individual therefore comparisons must be made based on similarities and probabilities (1). Another important biological unit is on hair. This area of expertise requires a compound microscope to observe and characterize different types of human and animal hair. Physics and chemistry are also integrated into this area because physics is used to determine the diameter of a hair sample (1). To do so, investigators and/or scientists measure the distance between bright spots of interference patterns on hair, using a laser pointer. When his technique is used it demonstrates the wave nature of light; refractive index. Many of the properties of hair are related to the chemical composition and structure of polymeric proteins and can lead to further discussion and investigation of natural polymers including DNA. Serology incorporates both biology and physics. Biological principles are used to determine whether or not a particular stain is blood spatter patterns, measuring the angle of impact, finding the velocity at which the blood hit the object on which it spattered, measuring the distance from which the blood was dropped, and finding the direction from which it spattered.

The application of trigonometry at this point is very important as well (1). Infrared Spectromicroscope Forensic Science is rarely absent from the news these days. Hardly a week seems to pass without reports of a criminal being convicted by DNA evidence extracted from a single hair; a flake of skin or a trace of blood or saliva found at a crime scene. Many, of the materials encountered at crime scenes are too small to be analyzed using standard instrumentation, even at infrared wavelengths.

However, the advent of “ infrared spectromicroscopy” has led to significant advances in forensics. Infrared spectroscopy is extremely powerful because infrared photons can couple directly to certain vibrational modes of molecules. Ultraviolet light excites broad electronic transitions, meaning that it cannot uniquely identify samples by measuring the frequency of vibrational modes of the compounds in a sample (2). Infrared spectroscopy has already been used to study a diverse range of samples, including crops, soil, thin films, powders and an abundance of biological materials.

Crucially, infrared spectroscopy allows crime investigators to compare a sample with a known compound or item in order to determine whether they share any chemical or physical properties with suspects involved in criminal investigations. Infrared in forensics applications has been limited by our inability to examine relatively small amounts of material with high spatial resolution and spectral sensitivity. The first team to combine microscopy and infrared spectroscopy was led by R.

Barer of Oxford University in the UK in 1949 (2). Simply speaking, Barer and co-workers passed a beam of infrared radiation through a diffraction grating to separate it into different wavelengths and then focused part of the outgoing light through a microscope onto the sample. Using a second microscope to detect the reflected light, they painstakingly measured the absorption as a function of frequency. These ideas led to the development of the first commercial microscope for infrared spectroscopy in 1953 (2).

In the past decade, however, spectromicroscopy has been revolutionized thanks to high-quality optics, inexpensive spectrometers and fast computers to process data. Modern infrared spectromicroscopes typically use the thermal emission from a filament heated to high temperatures. This light is then collected by a series of reflective optical elements and passed to a Michelson interferometer, rather than a diffraction grating to separate the light into different wavelengths. Michelson interferometers are used because they can transmit far more light than gratings (2).

The interferometer splits the incoming light into two beams – one of which reflects from a fixed mirror while the other reflects from a movable mirror – and then recombines them. This modulated light is then passed through an infrared microscope that focuses the light onto a small spot on the sample. Next, the intensity of the light reflected by the sample is measured by an infrared detector as a function of the mirror position. The resulting interferogram is then transformed to reveal the different frequency components of the signal.

This spectrum is simply the spectrum of the incoming light modulated by the frequencies absorbed or emitted by the sample (2). Recently, scientists have further decreased the size of the samples that can be studied by using synchrotron radiation in conjunction with infrared spectromicroscopy. Intense synchrotron beams allow the tiny amounts of materials that are collected at crime scenes to be studied (4). Indeed, forensic scientists are now able to study samples at a size and concentration level that before were impossible. Synchrotron radiation is hundreds of times brighter than conventional infrared sources because it can e focused to spot sizes just a few microns apart (2). So how has infrared spectroscopy helped in the fight against crime? Back in 1989, the authenticity of an instant-win lottery scratch card was questioned when it was submitted as a winning ticket in Connecticut in the U. S (1). Computer records show that the ticket was not a winner based on its preprinted serial number. Since attempts of forgery or alter lottery tickets are fairly common, forensic scientists researched this case carefully. A private company called Spectra-Tech was part of this case.

Scientists there obtained infrared spectra from various parts of the ticket and compared them with spectra from valid tickets. When the two sets of data were shown to match, the problem was deemed to a “ computer error” and the winnings were paid out to the winner (2). Like the lottery ticket, forensic scientists often try to identify other suspect documents from the infrared spectra of the ink, toners or markers, or the paper itself. The spectrum of ink on the counterfeit banknotes for example, does not match the spectrum obtained from real currency (3).

Forensic experts often use such data to identify the possible origin of the paper, to verify that the document is as old as it is claimed to be, and to check that the same ink is used throughout the document. However, one of the difficulties of analyzing ink is that the pigment must be extracted before it can be examined with infrared radiation. A group in Berkeley after researching this situation was able to use the intensity in radiation to make rapid and direct spectroscopic measurements of inks without having to chemically separate them from the paper (3).

Infrared spectroscopy has also proved a powerful tool in the fight against illegal drugs. The best results appear in pure samples. In one case in the late 1990s, police in Ottawa, Canada, identified a small piece of evidence using a combination of infrared spectroscopy and other techniques. They discovered small amounts of another contaminant in the sample that suggested that a drug had been manufactured illegally (4). In other cases, infrared spectroscopy is combined with other analytical techniques. Chips of paint, for example, are first examined with an optical microscope to determine the color, layering and texture.

Infrared spectroscopy, however, helps forensic analysts to determine the type of paint and its main components. In hit and run cases, for example, experts first compare paint chips found on the body or at the crime scene with a database of known samples and then use infrared spectroscopy to identify the year, make, and model of the car (2). Infrared spectroscopy also plays a role in the analysis of various types of fibers and in many cases it plays a crucial role in identifying the composition of the fiber unequivocally (1).

For example, while investigating a murder in Kern County, California, investigators found small fragments of red polyester fiber on the victim’s body and by using infrared spectroscopy; analysts matched the fibers to those found on the seats of the prime suspect’s car. As the future is still being planned, the applications of synchrotrons-based infrared spectromicroscopy to forensics are virtually limitless. Crime scenes offer many examples of composite vibrationally-active samples including blood smears on surfaces, mixed tissue and body fluids (10).

Infrared spectromicroscopy is ideal for examining the minute traces of blood found at crime scenes because high spatial resolution and high sensitivity are absolute musts. By using infrared spectroscopy, investigators are able to resolve issues such as the degree of decomposition of a body and the cause of death as well. Infrared radiation overall is likely to play an even greater role in the future of forensics. Applied Physics: Trajectories Topics of interest based on physics include motor vehicle accidents, trajectories of bullets, fire and explosion investigation, and materials identification and imaging methods.

One of the major applications of physics is Newton's Laws in falls from a height involving serious injuries and death (5). Physicist in forensics ask several questions such as did the victim accidently slip, trip, overbalance, or deliberately jump or dive or was the victim pushed or thrown? These questions are asked due to the fall being an accident, suicide, or a homicide. The trajectory of a fall is important, but there are other aspects of the fall that need to be taken into consideration such as the launch and landing phases of the fall (5).

Many calculations are made in this field of forensics in order to obtain accurate data such as measurements of the speeds at which a person can run, jump, dive, be pushed or thrown, an estimate of the rotational speed associated with each launch method, measurements or estimates of run-up and takeoff distances. These calculations are based on a few factors as well like launch angles and wind speeds, location of the center of mass of a person on video data, and an analysis of possible bounce and impact events (5).

For example, a person lands at a horizontal distance d = 9m from the building after falling from a height h = 30m the physicists would have to make several calculations and measurements of a typical jump, dive, and throw speeds of this kind to obtain and estimated conclusion. The horizontal distance traveled by a person from a given launch point to the first point of impact has three components that consist of the takeoff, flight, and landing distances. The flight distance according to the article is the horizontal distance traveled by the center of mass of the person through the air.

The takeoff distance, dT, is the horizontal distance from the center of the mass to the foot on the ground at the instant that the person become airborne. The landing distance, dt, is the horizontal distance from the center of mass to the first point of impact, and may also be around 05m. That means that in this case the horizontal launch speed required to jump a horizontal distance of 1m is therefore zero because a person can simply step that distance at essentially zero speed. The following equation is used in these calculations: D = v^2 sin(2)/g (5).

Many others argue these techniques due to the fact of air resistance, but physicists have proven that air resistance results in a small correction to the result as a headwind or tailwind. The main force on the body is that due to gravity. Also running and jumping speeds at really high altitudes are not common for non-elite athletes. According to Rod Cross, his research shows that a person can be pushed forward only about 1. 5m/s because the feet remain on the ground during the push and a strong male can throw a 60kg female into a swimming pool at speeds up to about 4. 8m/s.

In the specific measurements of running or jumping speeds also the physicist must take into account if the victim was on an inclined surface (5). Overall, the cause of an un-witnessed fall from a height, resulting in serious injury or death is often difficult to determine the physics of the fall can sometimes lead to a solution or at least help to eliminate some of the possible causes. Applied Physics: Event Reconstruction Physics tends to be straightforward – Newton’s Laws, thermodynamics, frictions, and etc. Event reconstruction is a major applied physics area in forensics.

In motor vehicle crashes, these scientists look for the coefficients of friction, how tires slide on the road when a car goes around a corner too fast (6). If there was a large acceleration at impact, the filaments of the lights – brake lights, tail lights, or turn signals may also play a role in these types of investigations. For example, a Boise State University physicist Richard Riemann was called to determine whether a baby was shaken or hit or whether an injury or death might have been from a fall (6). After his investigation, he had speculations about the idea that the child had a low temperature when they took him to the hospital.

He was able to conclude several data points with Newton’s law of cooling. He also determined the death of a victim from a cliff in Australia could not have been able to propel herself as far from the cliff as she landed. The cliff is 30m high and she was found almost 12m out. He concluded in this investigation that this victim had been thrown. Applied Physics: Other methods Lastly, some methods used for physical analysis in forensics are not always beneficial. A laser light beam has certain benefits, such as specificity, because the light beam travels in a straight line at a constant speed of 186, 272 miles per second to the target (7).

The drawback in using laser light are that it is somewhat difficult to work with in the daytime; it does not provide a complete sequence of beginning, middle, and end; it is subject to movement by the holder; it is unsteady in windy conditions; and it generally has a short range in bright sunlight conditions. Also the use of string in reconstructing crime scenes for certain types of evidence is a relatively simple, inexpensive and accurate method of demonstrating trajectory (9). Caution is emphasized when stringing a crime scene to determine trajectories due to the droop factor (the weight is shift towards the center of gravity) (8).

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