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Forensic Engineering Techniques to Reconstruct Shooting Incidents

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Abstract

This paper discusses and evaluates the techniques and technology available to reconstruct shooting incidents. Reconstruction typically involves movement of the shooter(s), their gun(s), victim(s), vehicles, and possibly witnesses. The analysis involves shooting range tests, photogrammetry, 3-dimensional computer modeling, bullet and shell trajectory analysis, and a time/space computer animation analysis. The bullet trajectories are re-created in 3-dimensional space and evaluated with the assistance of a 3-dimensional computer model created through photogrammetry. Today's technology allows engineers to reconstruct entire shooting incidents in a 3-dimensional time-space model where all the factors involved in the incident can be analyzed. Three case studies will be discussed.

Introduction

This paper presents methods used by these authors to reconstruct shooting incidents. The methods developed by these engineers and presented in this paper involve a unique combination of 3-dimensional computer modeling, coupled with photogrammetry, and a time/space computer animation analysis.

These engineers are often hired to reconstruct shooting incidents some time after the incidents have occurred. Often from the time of the incident until the time of hire, physical evidence has deteriorated. For example, if there was glass penetrated by bullets, typically, the glass has fallen in, or if there was a vehicle involved, tire marks are no longer visible.

The complexity of a shooting incident is due to the dynamics which occur during the incident. Often there are several independent factors contributing to the dynamics of the shooting incident, including motion of vehicles, motion of individuals or witnesses, and the orientation of the gun or guns. With all these independent factors, shooting incidents are very complex and difficult to reconstruct and require multi-disciplined approaches and analyses.

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These authors, over the years, have devised methods to reconstruct the dynamic factors associated with a shooting incident. Utilizing the following experimental and analytical methods and techniques, these engineers are able to reconstruct a variety of shooting incidents:

- Shooting Range Tests
- Shooting Range Test Analysis
- 3-dimensional Photogrammetry
- 3-dimensional Computer Modeling
- Bullet Trajectory Analysis
- Time/Space Animation Analysis

Shooting Range Tests

To begin each case, a series of tests are conducted at a shooting range with the actual shooter and the actual semi-automatic weapon(s) involved in the shooting incident. Valuable data can be retrieved from the tests including the location the bullet shells land after they have been ejected from the gun, known as the "shell ejection pattern". Shell ejection patterns are unique to each gun and are created by documenting the shell locations along with the location of the shooter in an x,y coordinate system. The shell ejection pattern in conjunction with the shell locations found at the incident scene are used to trace back to the location of the shooter at the time the shot was fired during the incident.

Shooting Range Test Analysis

The shooting range tests are also conducted with the shooter tilting and rotating the gun in an x, y, z-axis to give an even better understanding of the shell ejection pattern. An analysis of the movement of the gun at the time each shot was fired is also conducted. For example, if the shooter is running at the time the shot was fired, the trajectory for the ejected shell is influenced by the direction and speed the shooter is running. Bullet shell deformation, such as indentation or scratches is analyzed to determine if moving vehicles or pedestrian traffic has moved the shell from its original landing location. Often, such deformation indicates that the shell has been moved and the documented location is not the landing location.

3-dimensional Photogrammetry

Photogrammetry is a process used to scale images from photographs. If there are at least two photographs of any one item, taken at different angles, the item can be scaled using photogrammetry.

Typically, during the reconstruction, the vehicles are no longer in the condition they were at the time of the incident. Time and weathering effects such as wind cause broken glass to crumble and fall in and around the vehicle. When this occurs, the determination of the bullet trajectories is difficult without the physical evidence of the actual bullet hole. These engineers use photogrammetry to create scaled computer models of the vehicles involved in shooting incidents. Police photographs taken at the scene, just after incidents occurred, are used for the photogrammetry process to create accurate 3-dimensional computer models of the vehicles, which include the bullet holes in the glass. Typically, police photographs contain information that is no longer available during the inspection of the evidence. In instances involving a vehicle, police photographs show the bullet-ridden windows in the condition with bullet holes intact. Police photographs are valuable information because the models created are of the vehicles as they were just after the incident occurred, including the re-created bullet-ridden windows. With an accurate 3-dimensional computer model of the vehicle just after the shooting incident, these engineers are able to locate the bullet holes in the glass to re-create the trajectories of the bullets.

Photogrammetry can also be used for accident scene rectification of physical evidence that is no longer available at the accident site but appears in scene photographs, such as bullet shell location, tire marks or other debris.

3-dimensional Computer Modeling

The 3-dimensional vehicle model created using photogrammetry can then be imported into a 3-dimensional computer software package. The interior and exterior bullet damage to the actual vehicle is marked throughout the 3-dimensional computer model. The interior damage is then aligned with its corresponding exterior damage to create the trajectories of the bullets through trial and error approach. With all the interior and exterior damage aligned, a reconstruction of the sequences of events that occurred during the incident is performed.

Bullet Trajectory Analysis

Bullet Trajectory Analysis is used to determine the direction of the bullets after the shots are fired. Trajectory analysis begins with the analysis of the interior and exterior damage to vehicles and aligning the damage to the bullets inlet and exit on the 3-dimensional computer model. Autopsy photographs and reports are also used in determining the trajectories of bullets both before and after they travel through victim(s). The analysis techniques used by these engineers take into account all aspects of the bullet path including redirection by rigid objects. After the trajectories are determined, the test data from the shooting range tests is incorporated to determine the location of the police officer when each shot was fired. Using the trajectory for each bullet with respect to the ground aids in determining the location of the gun at the time each shot was fired.

Time/Space Animation Analysis

After developing the 3-dimensional model of a vehicle or scene, a time/space animation analysis is conducted to create a simulation of the shooting incident in a time and space domain. The animation created is an accurate representation of the events that occurred during the shooting incident.

During the computer recreation of the incident, individuals can be placed in their corresponding positions and the trajectories of each shot aligned with each shooter. After all the elements are in place, the animation is set in motion to illustrate the shooting incident in a time and space domain.

Case Studies

Below, three shooting case studies are presented. These investigation results have been presented in state and federal courts as well as in deposition testimony.

Case Study #1:

The first case study occurred during a police chase that involved one police officer and one felon fleeing from the officer on a remote dirt road. This case began when a trooper initiated a routine traffic stop that turned into a high-speed pursuit. The pursuit occurred at speeds up to 80 mph until finally ending on an unmarked farm access road, as seen in Figure 1. After the vehicle came to a stop, the man exited his vehicle and walked toward the trooper. When the man reached the front of the patrol vehicle, he bent down and appeared to pick up several objects. The man then moved to the passenger side of the patrol vehicle and threw an object that struck the antenna mounted on the patrol vehicle light bar. The trooper had drawn his service pistol at this time while the man made threatening statements and began to move toward the trooper. In response to the man's advance, the trooper retreated along the driver's side of the patrol vehicle and despite ducking to the right, was struck in the left shoulder by a rock thrown by the man. The man continued his advance on the trooper with a rock in his raised

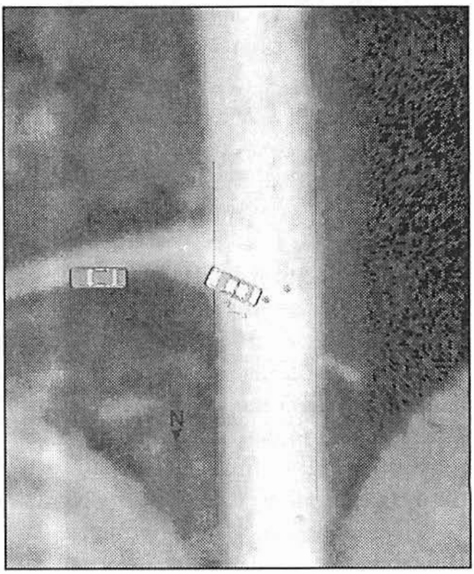

Figure 1

right hand. The retreating trooper perceived an imminent danger of death or serious injury to himself and fired a shot. The man continued to advance toward the trooper when the trooper fired two additional shots in quick succession, while continuing to retreat along the driver's side of his patrol vehicle, killing the man.

Techniques Used

Bullet Trajectory Analysis:

For case study #1, these engineers used the autopsy report and photographs to determine the trajectories of the bullets that entered the victim. The bullet wounds were placed in-scale on a 3-dimensional computer model of the man and the bullet paths were traced to determine the trajectories for each bullet. This information was used to determine the location and position of the man as the shots were fired. Figure 2 is the 3-dimensional computer model of the man with five bullets wounds from three bullet trajectories highlighted.

Analysis of the autopsy photographs and autopsy report indicates that wounds #2 and #3 are from the same bullet, wound #2 is the entrance and #3 is the exit. Likewise, wound #4 is the entrance for wound #5. The succession of the bullets began with wound #1, then wounds #4-5, and ending with wounds #2-3. The order of the bullets fired was determined using body kinematics. Wounds #2 and 3 are both located on the front of the man, due to the man's reaction to wound #4-5. Bullet #4-5 entered the man and he reacted by bending forward, therefore, the entrance and exit for #2-3 are located on the front of the man.

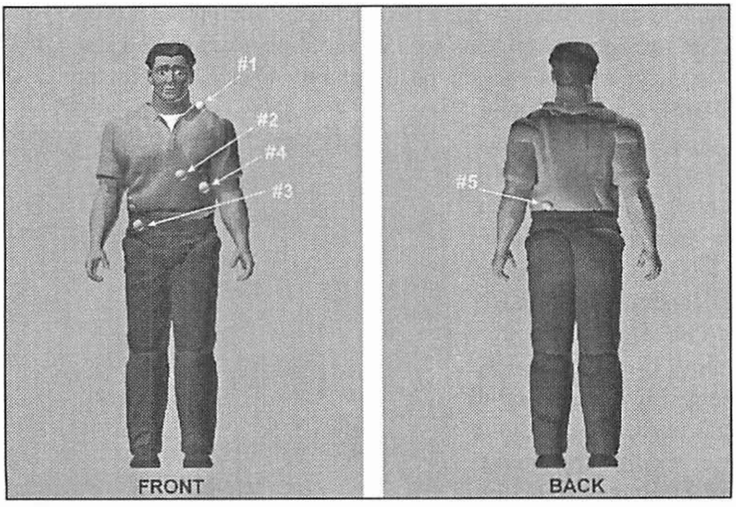

Figure 2

Another form of trajectory analysis is to determine the location of the shooter with respect to the trajectory height of the gun. Figure 3 illustrates that only at a certain distance could the trooper from case study #1 have fired his service weapon in order to cause the wounds to the man. The right side of the diagram depicts the location of the man as he was approaching the trooper. The trooper is depicted in two locations on the left side of the figure. For example, the left most shooter location illustrates that the weapon would have to be 17.6 feet off the ground in order to have caused the wound as illustrated in Figure 2. This indicates that for the shooter to have caused the wound in Figure 1, the man would have to be a significant distance closer and bending forward.

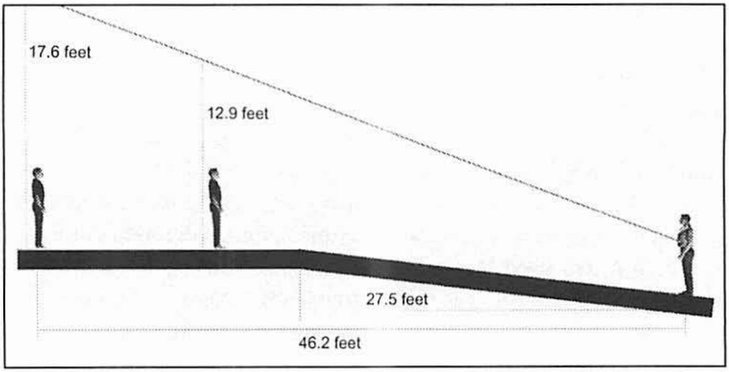

Figure 3

Case Study #2:

The next case study involved two teenagers attempting a robbery in a home located in a residential area, as seen in aerial photograph in Figure 4. The first officer to arrive on scene took a position in the backyard of the house while the other officer remained near the front. The two teenagers inside the house tried to exit through the front door but because the door was locked, ran to the back of the house and exited through the back door. The first teenager exited the house and was encountered by the officer in the backyard. The second teenager exited the house directly after the first, saw the officer and began a

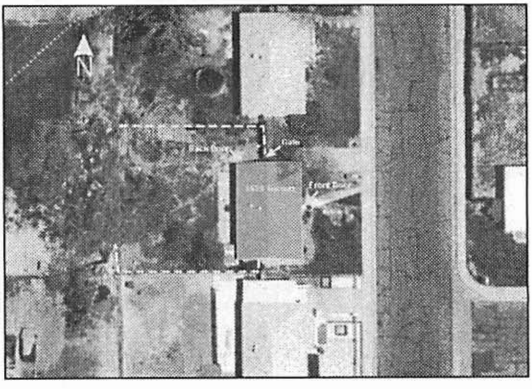

Figure 4

clockwise rotation toward the officer while holding a gun in his right hand. The surprised officer noticed the gun and attempted to get out of the path of the teenager's gun by ducking and then firing his weapon. A bullet struck the teenager in the neck as he proceeded to continue running for approximately 2 strides before falling to the ground. Evidence located at the scene included one bullet shell and a bullet impact mark found on a wooden board that was leaning up against a tree located in a corner of the backyard.

Techniques Used

Shooting Range Tests:

These engineers conducted shooting range tests with the actual shooter involved in the shooting incident as seen in Figure 5 and Figure 6. For case study #2, the first test was conducted with the police officer in his normal shooting stance as seen on the left side of Figure 5. Figure 6 is a photograph of the location of the evidence markers placed in the location of the shells. The location of the shells and the standing location of the officer were photographed and measured to create a database on the shell ejection pattern for the particular gun involved in the shooting incident. The data from the shooting test was plotted in scale and used to determine the location of the officer at the time the shot was fired during the shooting incident in question.

Figure 5

Figure 6

Figure 7

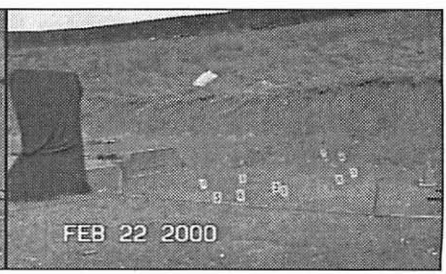

Figure 8

For case study #2, a second test was conducted in conjunction with the statement of the officer as he recalls the shooting incident. For this particular test, the officer was not in his normal shooting stance but was moving to his left, in the process of bringing up his service pistol and progressing in a forward motion, as seen on the left side of Figure 7. The dynamics and the motion of the officer caused the shells to be ejected in a forward manner as compared to the results from the first test, as seen in Figure 8. The data from this shooting test was also plotted in-scale and used in determining the location of the officer at the time the shot was fired during the incident in question.

Shooting Range Test Analysis:

After the shooting range tests are complete, the data is plotted in scale on a diagram depicting the shell ejection pattern. In Figure 9, the data plots from case study #2, as detailed above, are shown in the diagram. Notice that during the dynamic test, the shell ejection pattern is located in the positive y direction, while the results of the static test are in the negative y direction. This analysis illustrates the influence of gun/shooter dynamics on the shell ejection pattern rest position.

A 3-dimensional analysis of the incidents can also be performed if needed, to consider the tilting angle of the firing gun (up or down, left or right) as well as the effect of the shells ricocheting off moving vehicles. Generally, the bullet shells are analyzed for damage caused by moving vehicles or pedestrian traffic. If the shells show damage, the documented location of the shell may be affected by such traffic.

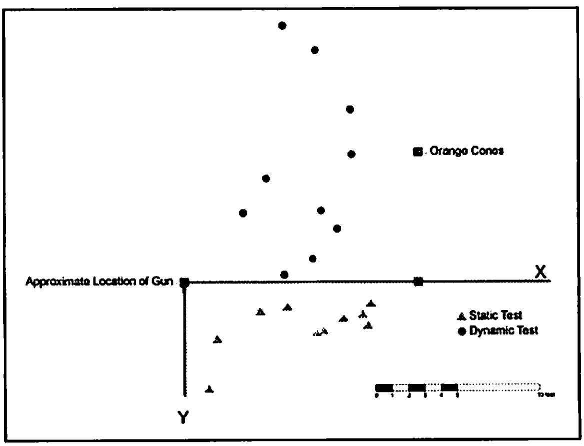

Figure 9

Case Study #3:

The last case study involved a vehicle and two off-duty police officers. This shooting incident occurred after midnight in a parking lot just outside a bar. The patrons from the bar began filtering out when a fight was initiated. As two off-duty police officers from inside the bar proceeded to investigate the disturbance, the events of the early morning began to unravel. As the officers were approaching to investigate a stationary vehicle located in a parking lot, the vehicle abruptly backed up, striking one of the officers. With the police officers firing their weapons to stop the vehicle, the vehicle continued in reverse. After the vehicle finished backing up, it began to move forward traveling toward the officer as he was coming to his feet. Several of the bar patrons witnessed the incident but none of the statements given were consistent. During this shooting incident, 25 shots were fired by two police officers while running alongside the moving vehicle.

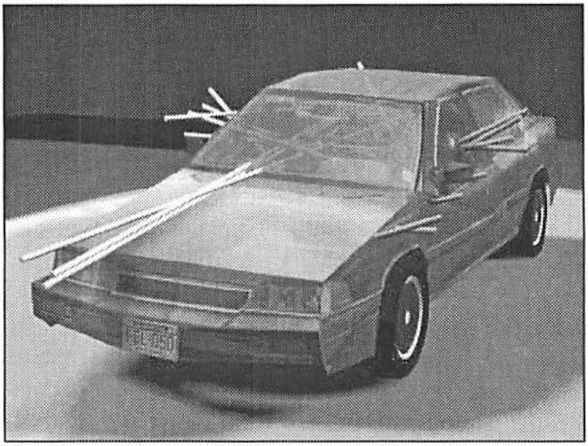

Figure 10

Techniques Used

Photogrammetry:

The process of Photogrammetry involves referencing common points on photographs taken at different angles of a particular object. In case study #3, photogrammetry was performed on an Acura Legend, as seen in Figure 10. Figure 10 is the photogrammetry model of the Acura created by these engineers with the bullet trajectories highlighted.

Photogrammetry was necessary because when the vehicle was first inspected by these engineers 1 1/2 years after the incident, the windows were no longer intact and had fallen in, as seen in Figure 11. By using photogrammetry, these engineers were able to use photographs taken by the police just after the shooting incident occurred, combined with photographs taken during the

Figure 11

inspection, to create a full 3-dimensional computer model of the vehicle in the condition just after the shooting incident occurred.

3-Dimensional Computer Modeling:

For case study #3, a 3-dimensional Computer model of the vehicle was created using photogrammetry. The photogrammetry model is depicted in Figure 12. Figure 13 is the photogrammetry model of the vehicle with a 3-dimensional model of the vehicle interior. For Figure 13, the outer layer of the photogrammetry model is faded in order to view the interior. The 3-dimensional model of the vehicle was necessary to align the interior bullet damage with the exterior bullet damage to determine the trajectories for each bullet.

Figure 12

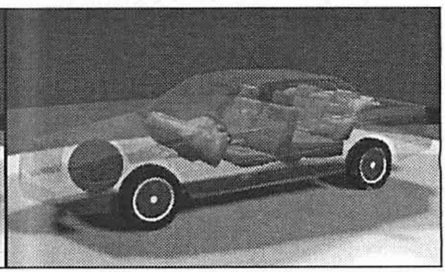

Figure 13

Time/Space Animation Analysis:

Using an animation software package, a time/space analysis was created by placing the 3-dimensional computer model on a scaled aerial photograph of the incident scene for case study #3 and as seen in Figure 14. The vehicle was then animated moving through the incident scene. The speed of the vehicle in the computer reconstruction was verified through vehicle acceleration testing performed at the incident site by the engineers. During the computer re-creation of the incident, the officers were placed in their corresponding positions in relation to the vehicle. With the officers in their positions, the trajectories of each shot were aligned with each officer. The animation was then set into motion. This motion was then analyzed to determine whether the movement of the vehicle and the officers complied with the rules of physics.

Figure 14

Conclusion

Utilizing the technology and methods presented in this paper, these authors are able to recreate entire shooting incidents. Engineering applications of computer 3-dimensional graphics, together with a time/space animation analysis of moving people and vehicles, as well as a utilization of field test data, allows these engineers to develop a successful procedure allowing the reconstruction of very complex shooting incidents. Such technology has been utilized in courts at the Federal and State levels, as well as in depositions.

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