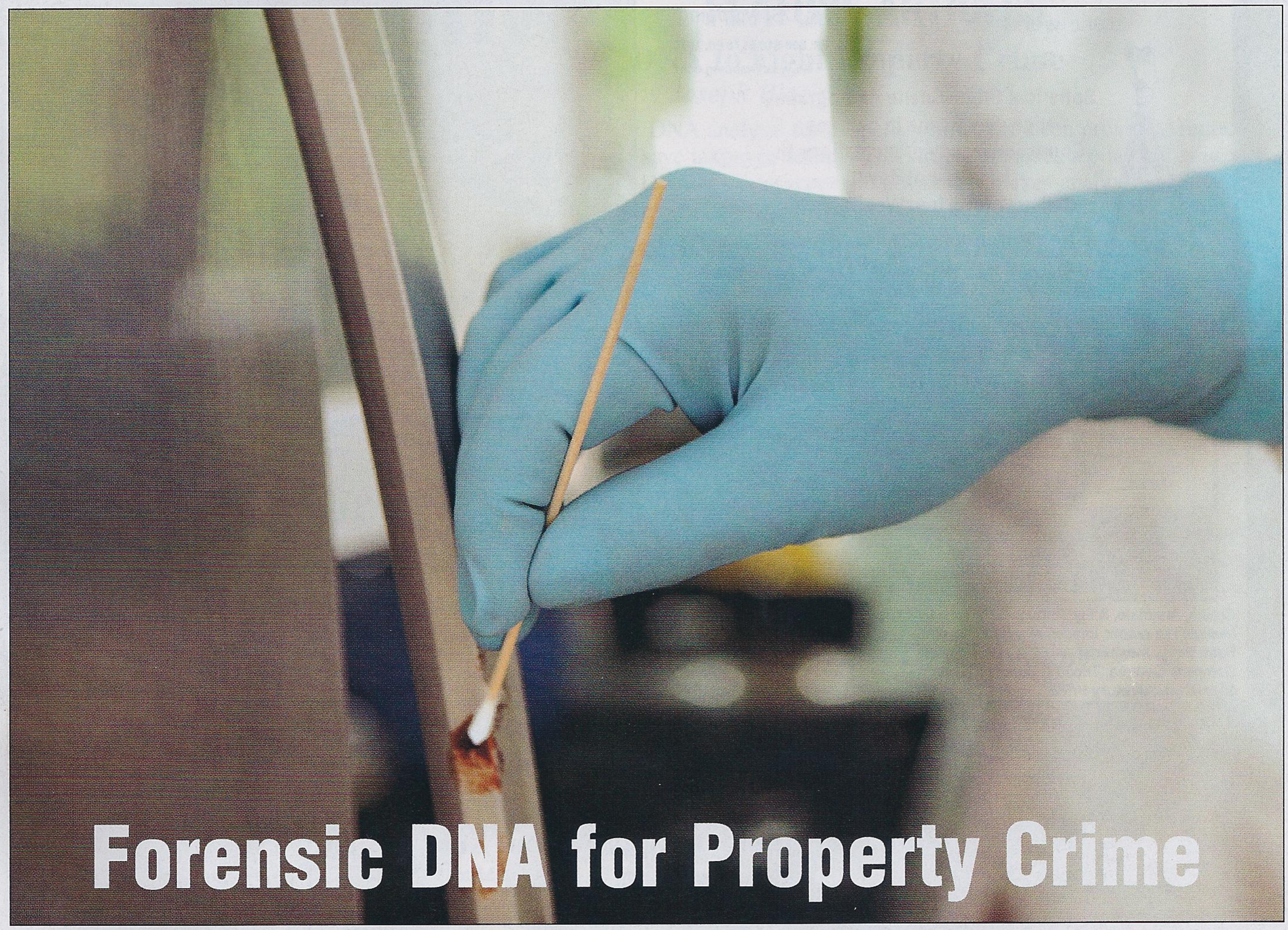
EVIDENCE TECHNOLOGY MAGAZINE

The magazine dedicated exclusively to the technology of evidence collection, processing, and preservation
Volume 10, Number 5 • September-October 2012



TOPICS IN THIS ISSUE

- Teleforensic Comparison Microscope
- Accident Reconstruction
- One-Step Cyanoacrylate Development
- Cell-Phone Forensics

Close-Range Photogrammetry for Sightline Obstruction Determination

Written by Lee DeChant and Gary Cooper

IN VEHICLE ACCIDENTS that involve personal injury, photography can often play a critical role in proving or disproving statements made in litigation. Close-range photogrammetry (CRP) techniques are used in accident scene reconstruction to derive accurate three-dimensional (3D) measurements from photos taken at the time of the event. CRP is a proven measurement technique that can extract 3D information from two-dimensional photographic images.

This article reports on the investigation of a crash where a car was turning left from a private road onto a U.S. Highway and was struck on the driver's side by an oncoming SUV. The plaintiff's complaint in ensuing litigation centered on the fact that a snow pile adjacent to the private road gave rise to a dangerous sightline obstruction. The snow pile, shown in *Figures 1* and *2*, allegedly prevented the driver from seeing the oncoming SUV that struck her vehicle as it entered the highway.

CRP was accomplished using numerous printed photographs acquired by the police shortly after the incident. The 3D photogrammetric measurement and modeling of the snow pile, along with other pertinent evidence, proved to be a key factor in the jury's 13-0 decision in favor of the defense, and hence no fault was attributed to the parties being sued.

The Incident

The crash involved a 1989 Ford Bronco II (SUV) and a 1996 Chevrolet Cavalier (car) that collided on February 23, 2003. The SUV was traveling eastbound on U.S. Highway 40 in Belmont County, Ohio, approaching a private road on the south side of the highway. The car was exiting the private road to proceed westbound on U.S. 40.

Importantly, there was a pile of snow at the southwest corner of the intersection of the private road and U.S. 40. This had been placed there by the construction company that owned the private road. The car pulled out in front of the SUV and the two vehicles collided. The car driver was rendered a quadriplegic as a result of the crash, and she subsequently sued both the SUV driver and the construction company.

The issues addressed within the crash reconstruction concerned the velocity of the SUV, the time/distance relationship between the SUV and car, and whether the snow pile restricted the car driver's sightline to the approaching SUV. The car was equipped with an air-bag control module (ACM) that recorded the longitudinal change in velocity experienced by the car during the collision. The data from the ACM and momentum were used to estimate the velocities of the car and SUV at impact. The SUV driver applied the brakes and the SUV's tires created skid marks on the pavement prior to impact. Both the length of the skid marks and the impact velocity were calculated and used to determine the initial velocity of the SUV.

The legal action taken by the plaintiff was also directed at the driver of the SUV. However, after calculations by experts for the plaintiff and defense indicated that he was most likely not exceeding the speed limit at the time his vehicle began to skid, he received a summary decision from the judge and was dismissed from the case.

The Snow Pile Question

The dimensions of the snow pile were not recorded by the police during their investigation. However, the police did position a police car at various locations on the private road and checked the sightline west along U.S. 40 from each location. The police concluded that the snow pile was not a factor in the incident.

The plaintiff claimed the snow pile restricted the sightline of the car driver and thus posed an extremely hazardous

Figure 1—Police photos taken at the scene of a vehicle accident show a snow pile that presented a potential sightline obstruction.

situation that was the principal cause of the crash. In deposition, it was further claimed by the plaintiff that "photogrammetry" had been employed to accurately measure the height of the snow pile. The method used was to draw three yellow, horizontal lines across two police photographs that were recorded shortly after the incident. These yellow lines can be seen in *Figures 1* and *2*.

The plaintiff's team was not able to provide any mathematical basis or scientific methodology to support the determination of the height of the snow crest at 4.1 feet. This arguably unorthodox, so-called "photogrammetric" determination appeared to use the height of a Toyota Tercel as a reference to determine the snow-pile height. The differential height between the snow pile and the car was measured with respect to the three horizontal lines, independently on the two photographs. There was no evidence provided that the Tercel's height measurement was even in the same vertical plane as that of the snow pile measurement—failing to provide correction for image perspective and image scale difference, and not accounting for camera tilt.

Experts for the defense used the same four police photographs to carry out a more rigorous, truly multi-image photogrammetric analysis. The photographs provided a satisfactory diversity of viewing directions and photo-overlap of the snow pile to support image-based 3D measurement. The scene was also surveyed several months after the incident, after the snow had melted, using a total station surveying instrument. The purpose was to provide reference points of known position, these being referred to as control points. The control points were subsequently used within the iWitness close-range photogrammetry system to accurately determine the position and precise aiming direction of each of the four photographs. This process takes account of camera calibration and it provided a basis for determination of 3D measurement of points of interest on and adjacent to the snow pile via photogrammetric triangulation. *Figure 3* shows the array of measured 3D feature points within iWitness.

Scanned photographs were digitally processed within the iWitness software system using two processes: Focal Length from One Image (FOOM)—that determines camera position and orientation; and Zaraf—that assigns the necessary metric information to the scanned images to support photogrammetric analysis. The yellow-highlighted 3D points in *Figure 3* were the basis of the determination of six different locations for the snow-pile height, later used in a CAD program for further sightline obstruction analysis.

Figure 4 illustrates the iWitness user interface and the four specific police photos used for the photogrammetric measurement.

Photogrammetric Measurement Accuracy

In contrast to the serious doubts associated with the validity of the measurement methodology presented by the plaintiff, it was a straightforward matter to validate the accuracy of the multi-image photogrammetric technique through a comparison of the measurements performed using the total station. A number of features were measured by both the photogrammetry software and the total station. The agreement between the two approaches indicated a photogrammetric accuracy of generally better than one inch, as indicated by the check-distance results in *Figure 5*.

Moreover, measures of quality within the photogrammetry software indicated a high level of internal consistency within the photogrammetric measurement of the snow pile. *Figure 6* illustrates the photogrammetric network used to measure 3D feature points and determine representative snow pile heights.

Sightline Analysis

The 3D *XYZ* coordinate measurements from the iWitness photogrammetry software were imported into two different CAD programs—namely Rhinoceros and Crash Zone—in order to map the scene as illustrated by the diagrams of the collision in *Figures 7* and *8*. The HVE Highway Safety Research software from Engineering Dynamics Corporation was used to carry out the sightline analysis. The car was placed on the private road near U.S. 40 at various virtual locations within the HVE environment. The extent to which the snow pile affected the car driver's line of sight to the approaching SUV was then visually analyzed.

***Figure 2**—Three yellow horizontal lines were placed on these photos (see also Figure 1) by the plaintiff's team to determine the height of the snow pile. This method, however, was flawed.*

Figure 3—Various measured 3D feature points were plotted on this image using close-range photogrammetry software.

Figure 4—Four police photos were utilized in this reconstruction, as seen here in the iWitness photogrammetry software interface.

DIMENSIONS Black = Total Station, Green = iWitness Photogrammetry
Units are inches

FROM	TO	DESCRIPTION	MEASUREMENT
49	50	REFLECTOR TO REFLECTOR - VERTICAL	40.2 IN 40.4
48	49	REFLECTOR TO REFLECTOR - HORIZONTAL	25.3 IN 24.9
36	40	RIGHT SIDE OF SIGN - VERTICAL	36 IN 36.0
35	39	LEFT SIDE OF SIGN - VERTICAL	36 IN 35.7
35	36	BOTTOM OF SIGN - HORIZONTAL	48 IN 48.2
39	40	TOP OF SIGN - HORIZONTAL	48 IN 46.9
37	38	LEFT SIDE OF "A"	19 IN 18.2
38	44	RIGHT SIDE OF "A"	13 IN 12.6
42	43	RIGHT SIDE OF "N"	7.74 IN 7.8
****	****	TOP EDGE OF ALL BLACK MAILBOXES (NOT THE ORANGE NEWSPAPER BOX)	20 IN 19.5

Figure 5—In order to check accuracy, the distance between feature points was measured using a total station and compared against the measurements determined by the photogrammetry software.

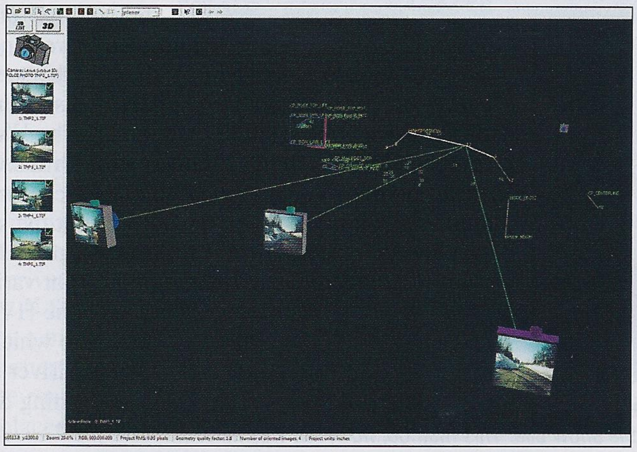


Figure 6—Here you can see the photogrammetric network used to measure 3D feature points and determine representative snow pile heights.

Figures 9 and *10* illustrate simulated views generated within the HVE system using the photogrammetric measurements of the snow pile. Along with the snow pile and roadway, other features of interest such as signage, road markings, and mailboxes were also shown in the virtual scene.

Using the HVE software, it was determined that with the car positioned two feet back from the fogline of U.S. 40 (*Figure 8*), the driver could have first seen the SUV when it was 400 feet from the intersection (*Figure 9*). The view of the SUV would have been significantly better at a distance of 250 feet from the intersection (*Figure 10*). With the front of the car at the fogline, the SUV could have first been seen by the car driver when it was 350 feet from the intersection.

Conclusion

The photogrammetric measurement work and subsequent sightline analysis formed a foundation that the defense used to build a successful case. The testimony on the crash reconstruction was compelling to the point that it was not challenged in any way during the trial.

This example of photogrammetric measurement to support forensic analysis highlights the general need for a 3D-modeling approach. The iWitness photogrammetry measurements—made from four images not specifically recorded for the purpose of scene reconstruction—clearly highlight the flexibility and accuracy of the multi-image photogrammetry approach. The height and feature-point measurements needed for the sightline analysis and visualization within a 3D-analysis program cannot be determined either rigorously or accurately from a single image—or from two images independently, as was attempted in the work carried out for the plaintiff. On the other hand, the photogrammetry approach performed for the defense can employ any number of images in order to provide a comprehensive 3D mapping of the accident scene.

(Continued on Pages 21 and 22)

(Continued from Page 20)

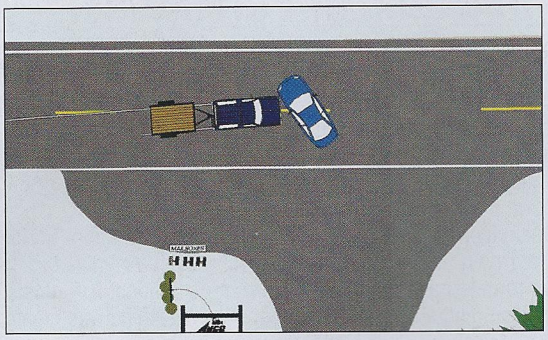


Figure 7—The accident scene mapped in Crash Zone.

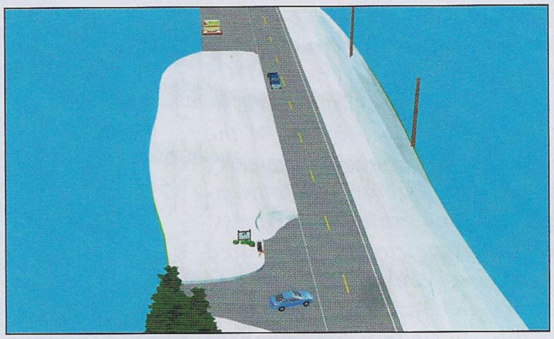


Figure 8—An aerial view mapped in HVE Highway Safety Research software.

Figure 9—The oncoming vehicle is first visible 400 feet from the intersection.

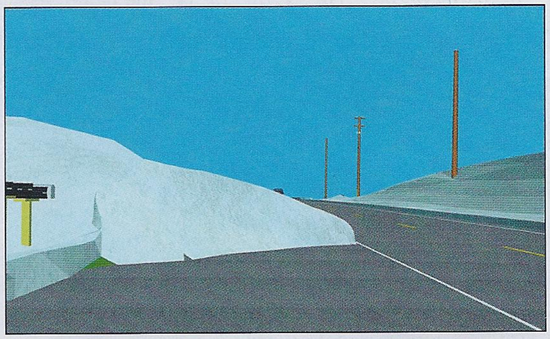


Figure 10—The view of the oncoming vehicle when 250 feet from the intersection.

(Continued from Page 21)

About the Authors

Lee DeChant is the Principal of DeChant Consulting Services—DCS Inc., of Bellevue, Washington. He is the co-developer and provider of the iWitness close-range photogrammetry software system, offering photogrammetric consulting, sales of iWitness, iWitnessPRO, metrically calibrated digital cameras, and a wide range of close-range photogrammetry products specifically designed for accident reconstruction and forensic image-based measurement. He can be reached at:

Lee@photomeasure.com

Gary Cooper is with Cooper Barrette Consulting, LLC, a traffic crash reconstruction firm in the Chicago, Illinois area, and is an instructor at the Northwestern University Center for Public Safety. He is a former Indiana State Police trooper and has an engineering degree from Purdue University. He can be reached at:

coopergw@att.net

Another Question of Perception:

Here is the very brief scenario:

A vehicle swerved around a large piece of agricultural equipment that was being towed down a roadway at night, clipped the machine, and collided with another oncoming vehicle. The accident resulted in the deaths of three people.

Joey Stidham, owner of Stidham Reconstruction and Investigation, LLC in Wooten, Kentucky, was asked to create an animated reconstruction that would help determine the driver's point of perception prior to the collision.

Unable to obtain the actual piece of farm equipment for the reconstruction, Stidham and his team constructed their own model of the agricultural machine involved in the accident. Testing then began to determine the driver's point of perception. A forensic map of the scene was completed, and a custom 3D model of the machine was created by reconstruction-software manufacturer Visual Statement.

The software, EdgeFX, was capable of producing dynamic lighting to aid in recreating the nighttime scene.

Night view

Day view

To view the animation that was used in court, go to this page in our Digital Edition:
EvidenceMagazine.com/v10n5.htm