Close-Range Photogrammetry for Sightline Obstruction Determination

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Introduction

In accidents involving personal injury, photography can often play a critical role in proving or disproving statements made in litigation regarding a vehicle incident. 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 on to a U.S. highway and was struck on the driver's side by an on-coming SUV.

The plaintiff's complaint in ensuing litigation centered upon 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 car's 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.

A snapshot of Photogrammetry

Close-Range Photogrammetry is a non-contact image-based technique for generating 3D measurements of objects and scenes from multiple overlapping photographs. It has traditionally been applied in topographic mapping, but through recent technological developments in digital cameras and personal computers, photogrammetry is now widely employed as a fast, accurate and easy to apply technique for measurement tasks including 3D modeling for heritage recording, engineering metrology and forensic measurements such as accident reconstruction.

The Incident

The crash involved a 1989 Ford Bronco II (SUV) and a 1996 Chevrolet Cavalier (car) that collided on February 23rd, 2003. The SUV was traveling east-bound on U.S. 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 left skid marks before impact. Both the length of these 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 situation, which 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 can be seen in Figures 1 and 2.

Figure 1

The plaintiff's team was not able to provide any mathematical basis or scientific methodology to support the determination of 4.1 feet for the height of the snow crest. The basis for this arguably unorthodox, so-called 'photogrammetry' determination appeared to use the height of a Toyota Tercel as a reference to determine 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, thus neither providing correction for image perspective and image scale difference, nor accounting for camera tilt.

Figure 2

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 (www.iwitnessphoto.com) 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*.

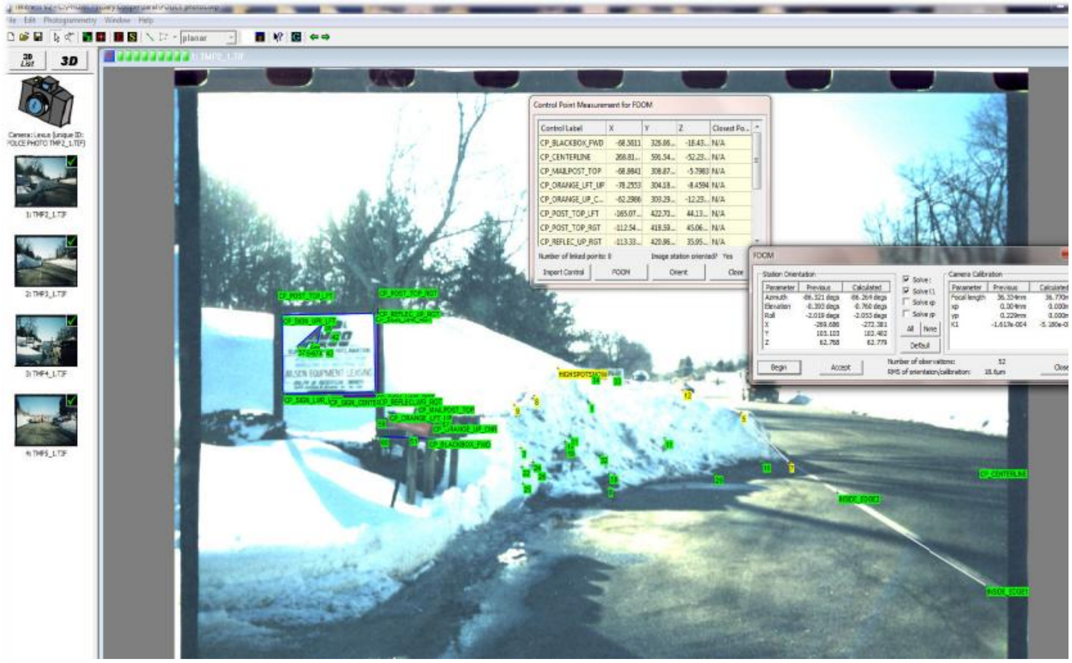

Figure 3

The individual processes used to enable scanned photographs to be digitally processed within the *iWitness* software system were *<u>F</u>ocal Length Fr<u>o</u>m <u>O</u>ne I<u>m</u>age* (FOOM), which determines camera position and orientation, and *Zaraf*, which assigns the necessary metric information to the scanned images to support photogrammetric analysis. The highlighted yellow 3D points in Figure 3 were the basis of the determination of six different locations for 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.

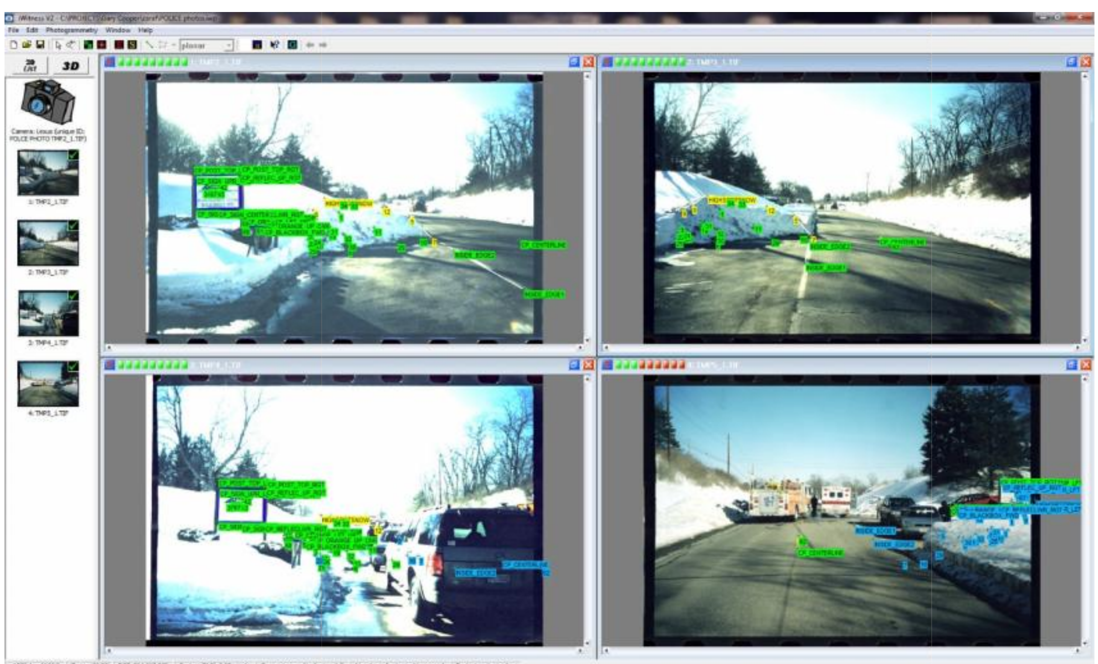

Figure 4

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 with the measurements performed using the total station. A number of features were measured by both *iWitness* and the total station and the agreement between the two approaches indicated a photogrammetric accuracy of generally better than 1 inch, as indicated by the check-distance results in Figure 5.

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

Moreover, measures of quality within *iWitness* 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.

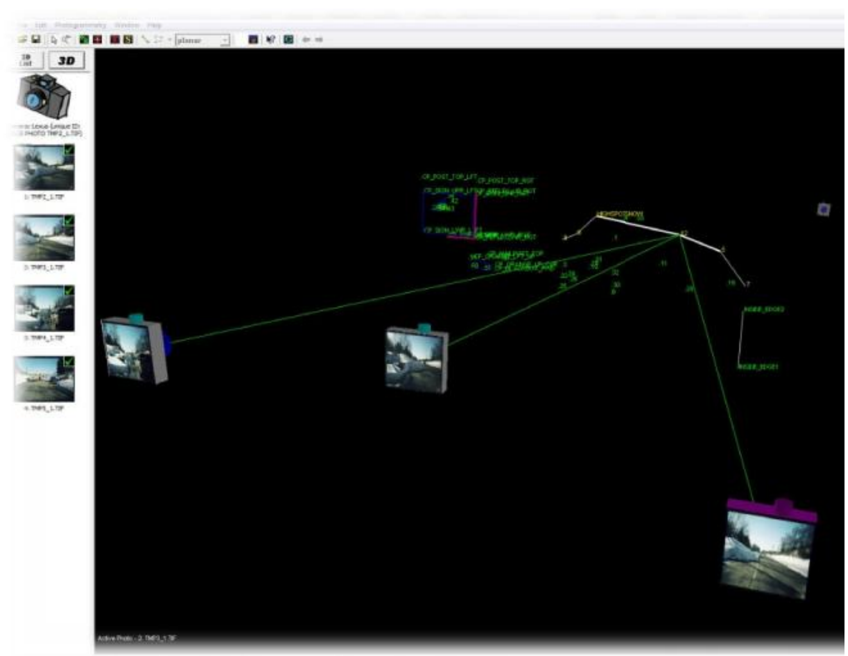

Figure 6

Sightline Analysis

The 3D XYZ coordinate measurements from *iWitness* 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.

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.

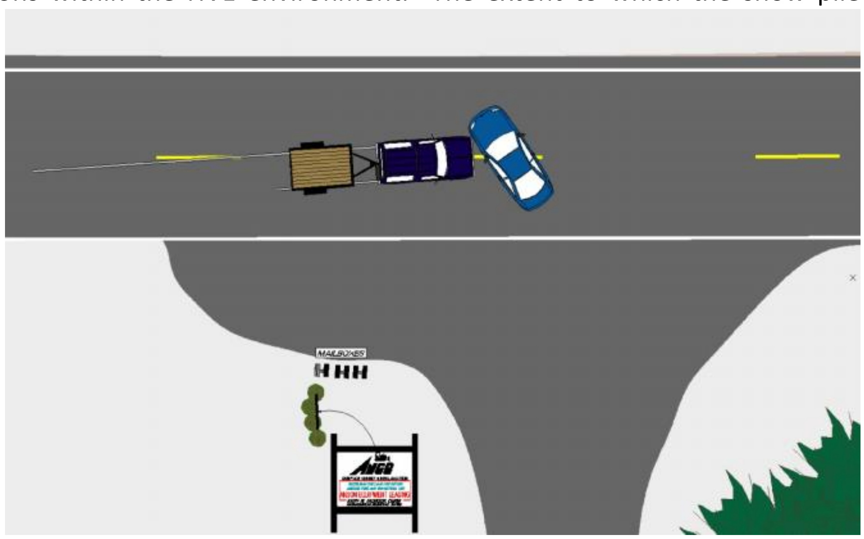

Figure7

It was determined through HVE 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.

Figure 8

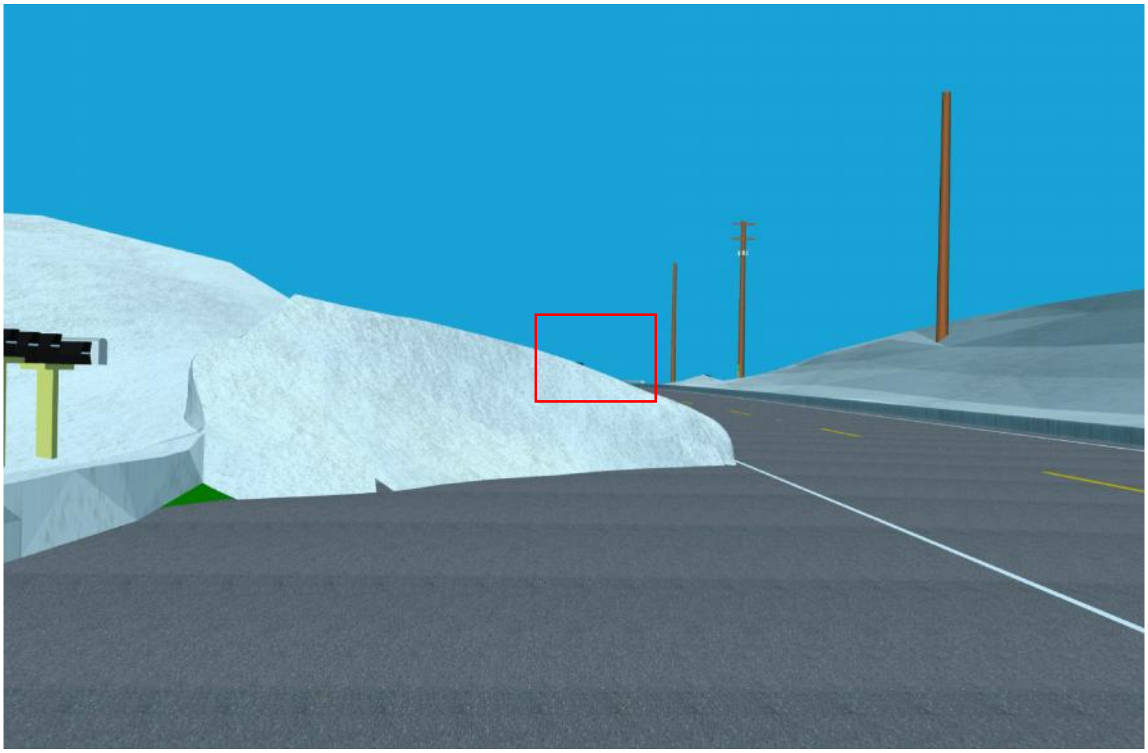

Figure 9

Figure 10

Conclusion

The photogrammetric measurement work and subsequent sightline analysis formed the foundation upon which the defense built its successful case, with the testimony on the crash reconstruction being compelling to the point where 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 highlights the flexibility and accuracy of the multi-image photogrammetry approach. Both 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 *iWitness* photogrammetry approach performed for the defense can employ any number of images in order to provide a comprehensive 3D mapping of the accident scene.