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Forensic Engineering Evaluation of Physical Evidence in Accident Reconstruction

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Abstract

Physical evidence deposited by vehicles as a result of an accident may not always be fully documented by the investigating law enforcement officers by means of measurements. Many times, the investigating officers are able to document the location of the vehicles at rest, but can only measure and locate some of the related tire marks and/or gouges that may be present on the roadway as a result of the collision. The officers may further supplement their investigation by photographing the scene of the accident. The photographs often depict the position and geometry of other physical evidence relative to the roadway or other geographic features. However, the forensic engineer may require more detailed information regarding the physical evidence than is shown in the photographs or measured by the officers, and must therefore take further steps to extract it. Depending on the evaluation required in the case, the forensic engineer would need to further analyze the accident by an inspection of the accident site and/or vehicles. After collecting the available information from the measurements made by the officers, the photographs taken at the scene, and the inspections by the forensic engineer, the data must then be compiled in a comprehensive form to further evaluate the dynamics of the accident. This paper discusses three methods (Camera Matching, Photogrammetry, and Rectification) of collecting the physical evidence from several sources and the procedure of producing a comprehensive forensic map of the evidence relative to the roadway and the dynamic motion of the vehicle.

Keywords

Forensic Engineer, Camera Matching, Photogrammetry, Rectification, evidence, rollover, roof deformation, physical, evidence.

Physical Evidence

Many times at the accident scene, the investigator or law enforcement officer will document what they consider to be "significant events" such as the beginning of a tire mark or the first gouge mark or the rest positions of the vehicles. Although this information gives the forensic engineer a snap shot of the

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events during the accident, it does not give the detail required to do a thorough analysis. The evidence and information located between the major events can provide further details as to the speed and position of the accident vehicles relative to the roadway that may be necessary for the analysis.

To determine the position of the vehicle between the points documented by law enforcement, a forensic engineer can use the photographs taken at the accident scene which show the physical evidence such as the tire marks shown in Figure 1.

To determine the location of the physical evidence, several methods can be used, including camera matching, photogrammetry, and photo rectification. In order to accurately place the evidence, basic dimensions of the roadway as well as any adjacent areas related to the accident should be determined by an inspection of the accident site, or from measurements taken by the officers at the scene, as-built drawings of the roadway, or aerial photographs. To further facilitate the process of determining the location of the physical evidence, more detailed or precise information regarding the roadway geometry can be used to improve the range of accuracy. To determine the exact roadway or median geometry, a laser survey can be performed by either a forensic engineer familiar with the equipment or a surveying company.

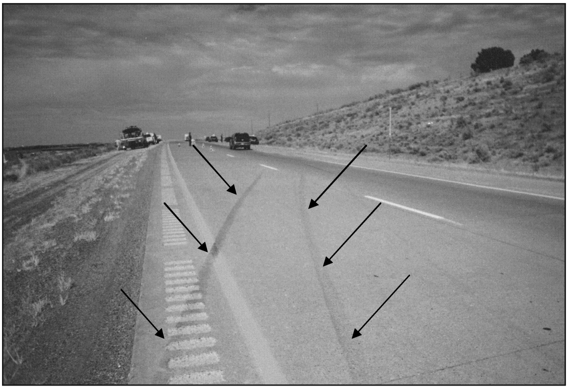

Figure 1
Arrows show the tire marks deposited on the roadway documented by law enforcement.

Once the available data is collected, camera matching, photogrammetry, or rectification can be performed. The following demonstrates each of those three processes.

Figure 2
Gouge marks and tire marks on the roadway photographed by the police but not measured.

Camera Matching

Camera matching entails the use of the photographs taken by the investigating officer at the scene of the accident shown in Figure 2.

Although the physical evidence from this rollover accident is visible in the photograph shown in Figure 2, the investigating officers did not measure any of the points locating the gouges and tire marks. Unfortunately, this evidence was not present at the time of the forensic engineer's inspection (four years after the accident occurred) but it was still an important piece of the analysis. To precisely measure the roadway geometry, a laser survey of the accident site was performed. The survey data was then used to create a three dimensional model of the roadway surface using CAD software. With the three dimensional data of the roadway imported into the computer program, the photograph, taken by the officers, can then be placed into a three dimensional software package, such as 3D Studio Max. Using the camera matching technique, a virtual camera is positioned relative to the 3D roadway surface with the same specifications and orientation as the camera used by the investigator. Once the camera is placed in that position, the physical evidence can then be mapped from the photograph onto the 3D roadway, as shown in Figure 3. Data obtained in this manner can then be used in the creation of a two or three dimensional accident scene drawing.

Figure 3
Gouge marks and tire marks on the roadway mapped in the scaled three dimensional accident scene.

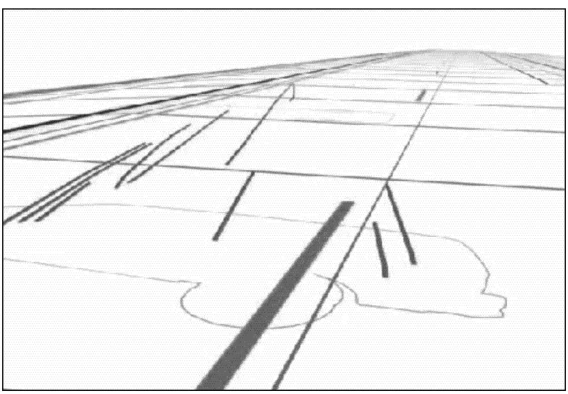

Figure 4
Physical evidence and gouge marks on the roadway mapped in the scaled three dimensional accident scene.

After locating the physical evidence, a scaled three dimensional vehicle can then be placed on to the accident scene matching the evidence as shown in Figures 4 and 5.

Once the engineer has established the position of the vehicle at specified points throughout the accident scene, a thorough analysis of the vehicles' position, attitude, velocity, and other dynamic properties can be performed.

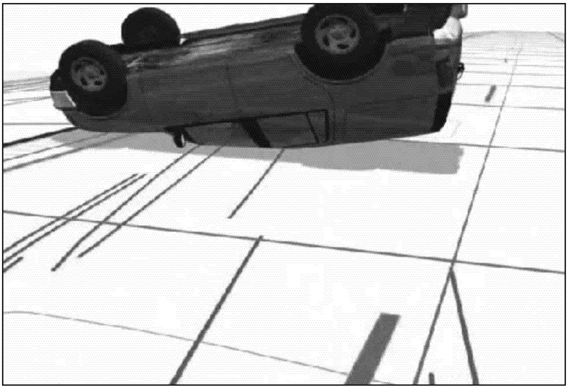

Figure 5
Three dimensional vehicle positioned on the scaled three dimensional accident scene diagram.

Photogrammetry

Another method of documenting physical evidence is through the use of photogrammetry. Photogrammetry is a technique that determines the three-dimensional geometry of an object on the accident scene from two dimensional photographs. The three dimensional coordinates of the objects in the photographs are determined after the virtual camera is positioned in the virtual space, and the specifications of the camera and the vanishing point in the photographs are determined and calculated.

In some cases, the only evidence available may be photographs. Even though the vehicles or tire marks may no longer be available, the photographs can be used to extract "lost" evidence. For example, a vehicle involved in a rollover may have been crushed or salvaged years before the engineer's involvement, but the deformation to the vehicle is still crucial to the investigation. To evaluate the damage, photogrammetry can be used on the available photographs to quantify the extent of the damage. With sufficient photographs taken from several positions around the vehicle and knowing certain dimensions of the vehicle, such as the wheel base, a scaled three dimensional model of the crushed vehicle can be produced.

The photographs shown in Figure 6 are of a vehicle that was involved in a rollover accident.

Photographs such as these can be imported into software such as PhotoModeler and then the forensic engineer can select points common in each photograph as shown in figure 7a and 7b.

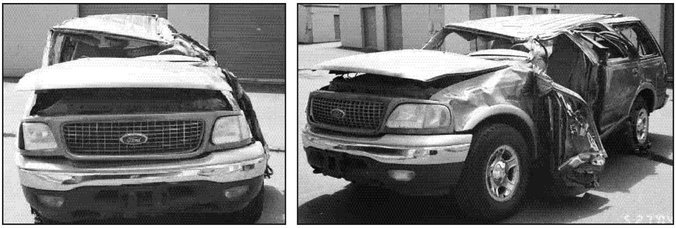

Figure 6
Damage to a Ford Expedition involved in a rollover accident.

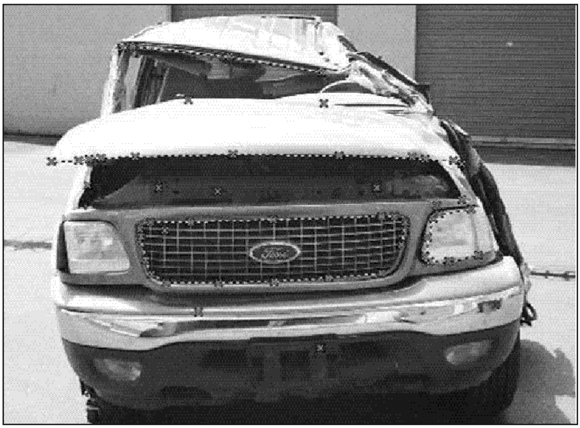

Figure 7a
Selected points on the damaged Expedition
exported from PhotoModeler

Figure 7b
Selected points on the damaged Expedition
exported from PhotoModeler

After the common points are selected on the photographs and the camera specifications are entered into PhotoModeler, then the software, based on known principles of optics and photogrammetry, can calculate the location of each selected point in a three dimensional coordinate system. The data can then be exported to a 3D software program to create an accurate scaled damaged model of the vehicle, as shown in Figure 8. Then the forensic engineer can use the model of the crushed vehicle to determine position, speed, intrusion into the occupant compartment, and forces the vehicle underwent during the roll sequence.

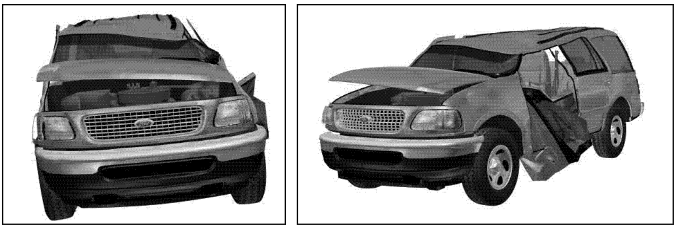

Figure 8
Scaled three dimensional model of the damaged vehicle.

Photographic Rectification

Photographic rectification is another tool the forensic engineers have at their disposal to analyze physical evidence that may not have been measured by the investigating officer. Two dimensional (2D) rectification is the process of transforming a single photograph which is oblique to a planar surface into an orthographic image or a top-down view. This simplified form of photogrammetry is applicable only to photographs in which evidence is located on a relatively flat, planar surface such as a roadway (a typical occurrence in vehicle accident investigation).

A software package such as PC-Rect can be used to import and rectify a digital photograph or digital scan of a photograph. The process involves the forensic engineer defining and locating known roadway dimensions in the photograph, such as lane line spacing, lane widths, etc. The program uses these dimensions to calculate the position, orientation, and specifications of the camera. If some or all of the information about the position of the camera or specifications are known to the engineer, the data can be entered into the software for increased accuracy.

The rectification process itself can be visualized as the reverse of the photographic process. When the photograph is taken, photons of light are projected from the road surface, through the camera lens and the focal point of the camera, and onto the image plane (the film). For the 2D rectification transformation, it is assumed that the point on the road, the focal point of the camera and the point on the image plane are collinear. To rectify the photograph, the "light" is projected from the camera position (the focal point), through the image plane and onto a planar surface. The resulting bitmap image has the appearance of taking the photograph and stretching it onto the roadway. With the proper definition of the area to be rectified and good reference dimensions in the photograph, high accuracy can be achieved, resulting in scale images in which measurements of evidence important to the accident investigation can be taken.

To rectify an image, the forensic engineer begins with a photograph taken by the officer at the scene (Figure 9). Within the photograph is a critical tire mark that has been highlighted with an ellipse (Figure 9). The forensic engineer next must define the area to be rectified (Figure 10a) and input the known roadway dimensions (Figure 10b).

Figure 9
Police photograph with tire mark identified with ellipse

Figure 10a (left) and 10b (right)
Definition of area to be rectified (10a) and
defined area and distances in PC-Rect (10b)

Once the dimensions in the photograph are defined, the software uses that information to calculate the position, orientation, and specifications of the camera. As described above, the resulting product is a scaled orthographic image of the physical evidence on the roadway, as shown in Figure 11, which the forensic engineer can use in reconstruction analysis.

Conclusion

Overlooked or undocumented evidence can be retrieved and quantified as long as photographs of such evidence are available. Using photographs taken at the accident scene or of the vehicle, "lost" evidence can be scientifically and accurately determined using several methods, such as camera matching, photogrammetry, and rectification.

The accuracy of the photogrammetry methods are a function of the quality of the photographs, available dimensional data, and skills of the forensic engineer. The more information available, documented, and collected by the forensic engineer, the greater the accuracy in the foundation of the analysis.

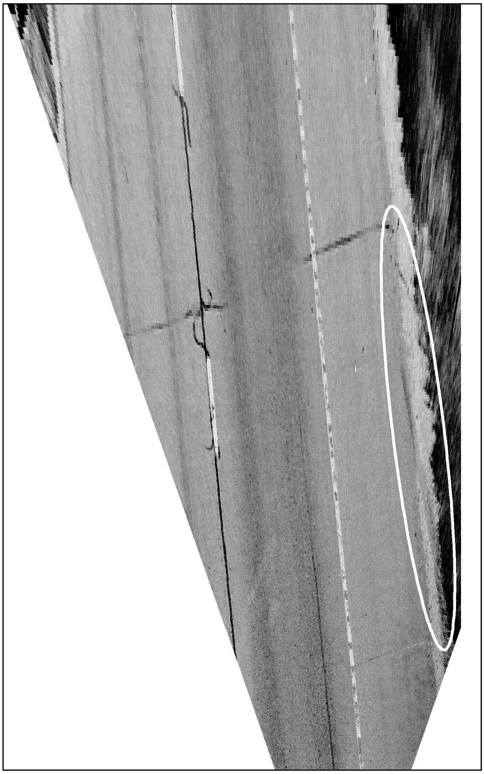

Figure 11
Orthographic image of the physical evidence on the roadway (critical tire mark has been highlighted with an ellipse)

The available techniques to retrieve the evidence such as camera matching, photogrammetry, and rectification are well-accepted and published scientific methods, and have been accepted by State and Federal courts, and have successfully passed Daubert challenges.

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