

Benefits of 3D Laser Scanning in Vehicle Accident Reconstruction

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Introduction

Accident reconstruction is the practice of determining how an accident occurred through the analysis of evidence and application of physics principles. Vehicle accident reconstructions are typically performed by forensic experts, investigators, specialized units in law enforcement agencies or private consultants and provide valuable information for a number of purposes including litigation, fault determination, road and highway safety, and vehicle design.

Documentation of accident scenes and vehicles is a critical component of accident reconstruction and there are many methods, tools, and processes to accomplish this. This paper discusses commonly used tools and methods for documentation, compares their accuracy, and highlights the advantages and disadvantages between them. In addition, the specific benefits and applications of laser scanning in accident reconstruction are discussed.

Measurement Methods & Equipment

Accident reconstruction experts rely on measurement tools such as tape measures, total stations, and 3D laser scanners to document evidence such as tire marks, gouges, debris, and vehicle deformation. Evidence is commonly documented using these tools, however, they do not all yield the same results. They may differ in such aspects as level of precision, ease-of-use, and the rate at which data is collected. The following paragraphs outline the differences, advantages, and limitations inherent with these tools.

Survey Method 1: Baseline

Baselines surveys are a method for documenting accident scenes that employ handheld equipment such as tape measures or the roll-a-meter, as shown in Figure 1.

Using this method involves identifying a reference, or starting point, and then measuring from this point along and perpendicular to an established baseline (such as fog-line or the edge of the pavement).

By recording the distance along the baseline and the distance perpendicular to the baseline, the position of evidence from a crash or other important scene features that existed prior to the crash, such as roadway signs and lane striping, can be located and transcribed to a scaled diagram. This method requires minimal tools and training, but is also susceptible to error and may be inadequate for certain types of analysis.

For example, a roll-a-meter has limited accuracy and error can accrue over long distances since rolling over rocks, cracks and debris can increase or decrease the total length measured. In addition, this method records positions in only two dimensions (x and y). This can be an issue when elevation (z-axis) is a contributing factor in an accident, since a baseline survey does not collect this information. Lastly, because it is a manual process, it is time consuming and often results in obtaining fewer data points than needed for complex reconstruction analysis.



Figure 1 - Baseline Survey measurements using a roll-a-meter

Survey Method 2: Total Stations

Total station surveying is a highly accurate method for taking measurements of accident scenes. Since the coordinates of the evidence and scene features are determined by a laser, the level of accuracy is much higher than it would be when using roll-a-meters and tape measures. The total station records the x, y, and z position of a surveyed point, allowing descriptions to be assigned to points, which saves time in creating scene drawings and during analysis later on.

Another benefit of this method is that evidence or scene features that might be difficult to obtain with a walking wheel can be obtained by shooting the total station at a prism that is mounted on the top of a pole and is held by another person, marking the location of evidence with the bottom of the pole. Total stations, as shown in Figures 2 and 3, can also be used for other purposes such as documenting the profile of a damaged vehicle involved in the accident. This dual role can be beneficial since combining both the location of the evidence at a scene with the damaged profiles of the vehicles are key elements needed to perform a typical reconstruction.



Figure 2 - Total station survey method: Accident Scene



Figure 3 - Total station survey method: Accident Vehicle

The additional equipment and computer controller needed with the total station make it bulky and expensive to transport. In addition, its dual use in surveying vehicles is limited. A damaged vehicle has

so many individualized components that need to be surveyed that a total station survey may simply not contain enough information for the required analysis.

Survey Method 3: Laser Scanning

Modern laser scanning is a fast and simple method of collecting three-dimensional data with a single device, eliminating the need for additional devices, cables or laptops on-scene. Laser scanning can capture incredibly detailed 3D data sets of complex environments and large-scale geometry in a matter of minutes.

Laser scanners emit a laser beam from a rotating mirror out towards the scene being scanned. Most scanners can distribute the laser beams at a vertical range that does not include the area below the scanner (approximately 305°) and a horizontal range of 360°. The laser beam is then reflected back to the scanner by objects in its path. The distance is calculated since both the time the laser takes to travel and its speed are known. This distance, along with the vertical and horizontal angles for every point, is then captured to a memory card, allowing for easy and secure data transfer to any computer for later analysis.

Many 3D scanners also have internal cameras allowing image data from photographs to be recorded onto the scan data. Multiple scans of an area or object are aligned using either targets that are strategically placed throughout the scene or geometric surfaces common in the set of scans. The resulting data set is referred to as a “point cloud” and consists of millions of individual points that have their own x, y, and z coordinates. Figure 4 shows a 3D laser scanner, the FARO Focus^{3D}.



Figure 4 - 3D Laser Scanner: FARO Focus^{3D}

Modern laser scanners provide accident reconstruction experts and forensic scientists with an efficient way to collect data points when inspecting accident scenes and vehicles. Quickly gathering measurements at speeds approaching one million points per second, laser scanners provide a combination of speed, accuracy, comprehensiveness, and ease-of-use not seen in conventional survey methods.

Figure 5 shows individual 3D points obtained during a survey with a total station, while Figure 6 shows the 3D points that were obtained at the same location but utilizing a 3D laser scanner. The density of the points from the 3D scan is so high that the surface of the road is even visible.

Due to the vast amount of data collected by 3D scanners, the resulting point clouds can be cumbersome. While optimized to handle this amount of data, software required for processing and working with survey point clouds can be expensive and memory intensive for computers. 3D scanners and their accessories are also more expensive than the surveying instruments mentioned in the other methods. For example, a tape measure can cost 750 times less than a total station, while a 3D scanner can cost 3 times more than a total station. However, with the increase in cost, there is a sizable increase in the speed, accuracy, and thoroughness of collected data.

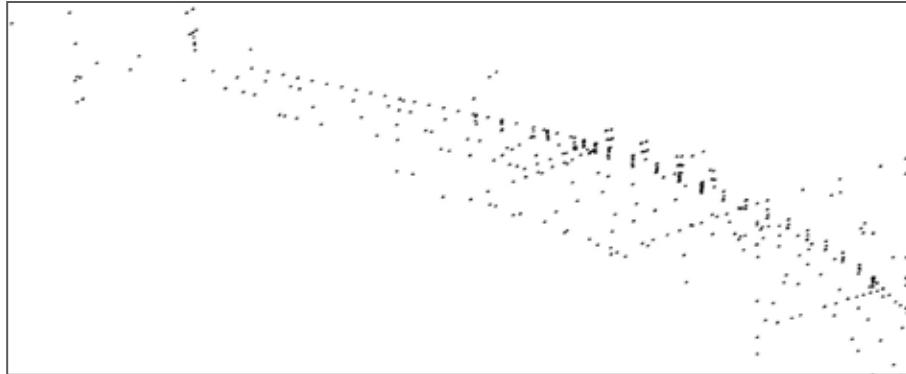


Figure 5 - 3D points of an accident scene using the total station method

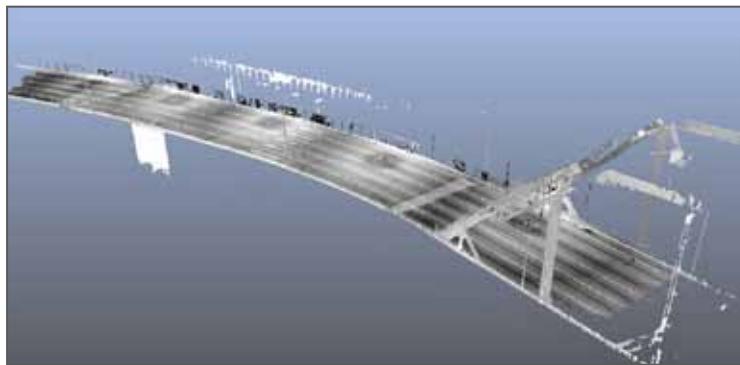


Figure 6 - 3D points of the same accident scene using the 3D laser scanning method

A Comparison of the Three Methods

The three above mentioned measurement methods vary in the type of equipment used, the number of data points that can be collected in a limited time frame, and the skill required to operate the equipment. Less time required, increased accuracy, and ease-of-use all rank highly as qualities needed by accident reconstruction experts, law enforcement personnel, and forensic scientists in their surveys. Among the survey methods described, only 3D laser scanning is able to meet these needs in a single portable device. Laser scanners are capable of collecting millions of points, at speeds approaching one million points per second, resulting in highly comprehensive and accurate point cloud models. The speed of data collection from a laser scanner allows accident reconstruction experts, law enforcement personnel and forensic scientists to minimize the amount of time spent on-scene, increasing their safety while reducing traffic congestion and road closure time to collect necessary measurements.

In instances where an accident vehicle has been made available for inspection, time is typically limited. Since the laser scanner can be started at the touch of a button, the operator is able to devote his or her attention to other areas of the inspection. Additionally, since the setup and collection of data is so simple, vehicle inspection can often be completed with one person. In addition to the ease-of-use and speed in data collection, laser scanners do not compromise on accuracy and data collected with a laser scanner is able to meet the rigorous requirements of court admissibility.

Applications for the 3D Laser Scanner

Roadway/Scene Evidence

Laser scanning can capture a vast amount of data at an accident scene, without having to pick and choose what information to gather. The laser scanner measures everything that it "sees" in its line of sight such as scene features, roadway curvature, sight line distances, and buildings - all of which can be analyzed during a reconstruction and used in highly accurate and detailed presentations, animations or simulations.

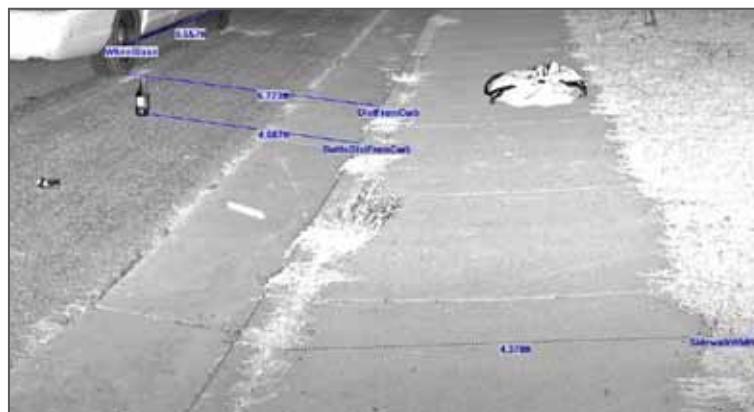


Figure 7 - 3D scan data with detailed measurements



Figure 8 - 3D scan data of a curved roadway with visibility obstructions

Figure 7 illustrates how detailed measurements can be obtained by analyzing the scan data and photographs captured during the scanning process. This detailed view of the scene can be created offsite, after the scan has been complete, by analyzing the scan data within a software program.

Figure 8 is another example showing a curved roadway passing through trees. By viewing this data within computer software, sight line distances and visibility obstructions can be easily evaluated.

Vehicle Scans

In addition to scenes, modern 3D scanners are designed for documenting vehicles in an accident. Scan data

of accident vehicles is useful to accident reconstruction experts in various types of analysis including crush deformation, impact configurations, and analysis of vehicle components.

Crush Deformation

In addition to needing timely, detailed surveys of accident scenes, vehicle damage and vehicle components such as the engine, wheels, or structure can be easily analyzed back at the office once the data has been collected with a 3D laser scanner.



Figure 9 - 3D scanning point clouds of an accident vehicle

Vehicle crush profiles, for instance, can be useful for determining vehicle speeds prior to impact. Obtaining these vehicle crush profiles from 3D scan data is both more accurate and more efficient than other surveying methods. Regardless of which measurements are required later in the reconstruction, a detailed laser scan will ensure that the 3D point data necessary for these measurements is available. Figure 9 is a screen capture of 3D point clouds from several scans of an accident vehicle. The point clouds have been aligned and color values from the scanner's internal camera have been applied.

Impact Configurations

When vehicles and objects involved in a collision are available to be documented with a 3D laser scanner, the resulting 3D point clouds can provide a more accurate 3D alignment of the vehicles with the objects they collided with. The ability to determine this impact configuration provides reconstructionists with better data to analyze a crash. Figure 10 is an image showing accident vehicle scans aligned in an impact configuration.

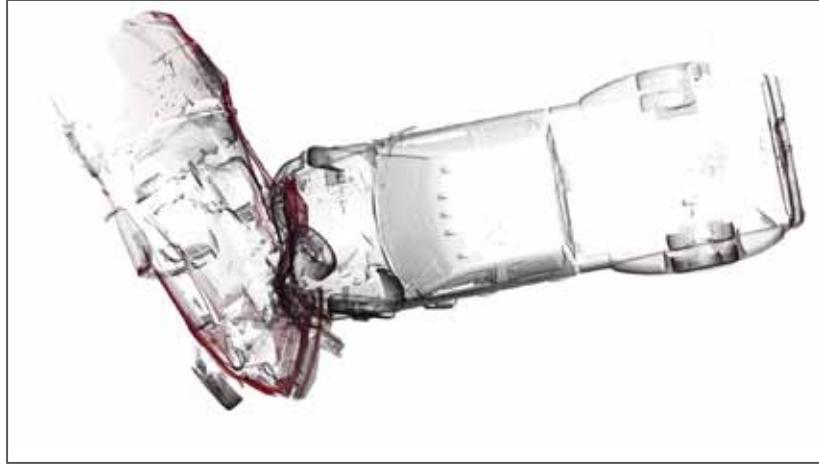


Figure 10 - An accident impact configuration determined using 3D scan data

Component Analysis

Vehicle components and their interaction during a collision sequence can be important to understand when analyzing specific events of a collision. These component interactions can be analyzed in detail using scan data.

For example, two vehicles can be placed in their position of maximum penetration to help visualize how the components from each vehicle engaged during the collision. Figure 11 is an example of a vehicle's engine components that were scanned when the hood was up.



Figure 11 - 3D scan data with vehicle components visible

Summary

Baseline, total station and 3D laser scanning are all common methods for surveying with their own respective advantages and disadvantages. While other survey methods exist beyond those discussed in this paper, these three methods are still in use and are the most commonly used throughout the industry. However, with the advent of laser technology and the need for digital data to be quickly analyzed and

transferred to other mediums for use by other experts, the 3D laser scanner has begun to separate itself as the tool of choice. The time savings in gathering both accident scene and vehicle measurements, as well as the comprehensiveness of the data provides a major advantage to accident reconstructionists in scenarios where timing and accuracy is critical.

**All images courtesy of Kineticorp LLC*

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