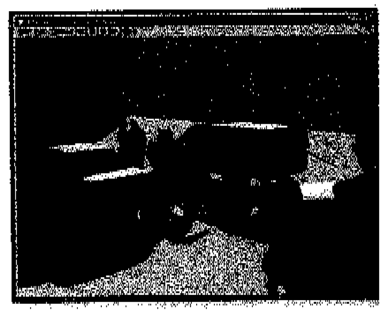
Shadowy Defense

3D Modeling at the Scene of the Crime

Jim Ebert



When a prostitution sting defendant filed an excessive force suit and a witness stepped forward with supporting photographs, the city of Albuquerque's defensive position seemed tenuous at best. The photos were clearly arresting, but did they really reveal a crime? Geospatial technologies and photogrammetric techniques helped to illuminate the shadowy details behind the damning photos.

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Images courtesy of Ebert & Associates

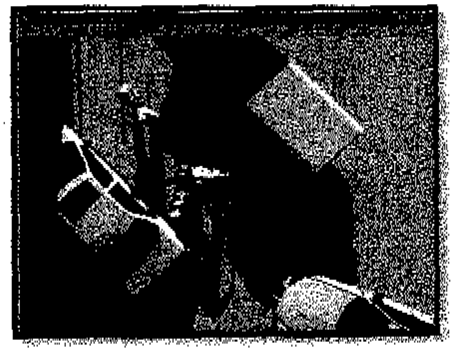
When Mr. Friday (remember Dragnet? We've changed the name to protect his identity!) inappropriately propositioned an undercover police officer in Albuquerque, New Mexico, in 1994, he set into motion a chain of events that would take years to unfold.

As soon as nearby police officers participating in the prostitution sting approached his small red truck, Friday realized his mistake and sped away. Unfortunately for him, he pulled into a parking lot with only one exit. His getaway was quickly blocked by two police vehicles. He made yet another mistake when officers ordered him out of his vehicle and he instead rolled up his window — trapping the arm of one of the officers who had reached in to try to remove the ignition key. After a brief struggle, the officers managed to open the door and arrest the would-be John.

What occurred during the few moments between the time police officers opened the truck door and when they arrested the suspect became vitally important months later when Friday filed an excessive force complaint against the officers and the city of Albuquerque. Supporting his suit was the fact that a witness had come forward with photographs she had taken of the incident. She alleged that her photographs showed Albuquerque Police Department officers mistreating the suspect. But did they?

What was really going on in the photos taken on the scene? That's the question the Albuquerque City Attorney's office asked our firm, which specializes in applying photographic and spatial data in legal cases, to answer in 1998 as the city prepared its defense.

We knew that spatial relationships among objects and people as well as lighting, visibility, and perception — in other words, the physical geometry of a scene — can greatly alter a witness's perceptions and



profoundly affect the court's evaluation of whether witness accounts are reasonable and believable (see "What's So Spatial?" sidebar). So we set out to analyze the spatial factors at play in the Friday case using a combination of highly accurate site mapping, photogrammetric measurement from the incident photos, and three-dimensional mapping and modeling. We coupled the technology with the logic of a forensic scientist and an investigator familiar with police procedures and strategies.

Through the lens

We began our task by obtaining copies of the photos. Even though they were snapped with an inexpensive motorized 35-millimeter camera, the photos are striking in regard to the scene they are alleged to portray. They are of technically poor quality, not because of the way they were developed and printed (by a standard one-hour photo provider) but because they were taken at a completely suboptimal angle into the sun. The problems with the photos are further compounded by light diffusion caused by dust in the air. Light flare from the sun and its reflections on vehicles as well as in the camera lens further degrade the photographs.

But put yourself in the place of the photographer, or someone to whom she was showing the photographs, and you can almost see what she believed she had viewed through the lens of her tiny camera. In Figure 1, the officers crowd around the driver's side of the truck, possibly extracting the suspect. A cloud of dust rises as officers bend over something in front of them on the ground (Figure 2). One of the officer's arms appear to be raised as if he may be striking the victim. (This motion is most apparent in the shadows.) The officers on the scene begin to rise in Figure 3 as a fourth

Glossary

CAD: Computer-aided drafting

GPS: Global Positioning System

What's So Spatial?

Police officers surround a subject who is shouting threats to officers or to the public at large. Suddenly, a man reaches into his coat, pulls out an object, and extends it toward the crowd. The officers open fire, only to find a few seconds later that the object was a comb or a wallet. The subject — or his survivors — inevitably file an excessive force suit against the police officers, department, and city. National and local headlines relate these stories almost daily.

Most excessive force complaints against police are founded on the oversimplistic premise that law enforcement officers are prone to overreact to threats, or that they are just plain mean. When individual cases are investigated, however, each is based on a unique set of circumstances and surroundings. Almost always, evaluating such cases revolves around questions of perception: What could an officer have seen and known versus what he or she might not have seen or known? What could witnesses have seen, and what was not visible to them? And, perhaps just as importantly in many situations, what were the perceptions of the subject or witnesses?

In every such case, visibility and perception depends on tangible features of the setting — the precise locations and spatial relationships among the subject, officers, witnesses, buildings, vehicles, trees and vegetation, and lighting.

Many facts about the scene of a violent incident are, perhaps fortunately, ephemeral. As quickly as violence erupts, it is over. Participants and crowds disperse. Crime scene investigators quickly take photographs and sketch maps, often under the worst of conditions and emotional duress. And yet, sometimes years later, minute details of what a scene was like at a precise instant become important in litigation.

Digital mapping, information management, and graphic technologies increasingly offer forensic scientists the tools they need to measure, reconstruct, visualize, and demonstrate exactly what happened when law enforcement personnel resorted to the use of force. In much the same way that archaeologists reconstruct the behavior of past people from stone tools and bits of pottery, digital geospatial technology can help forensic experts combine the parts of a scene that remain with other aspects that are no longer there.

FIGURES 1-3. At first glance, the photographic evidence provided by these images seems to support the plaintiff's claim of abuse. Officers crowd around the suspect's truck (top). Dust swirls as the police bend over an object (middle) then rise as a fourth officer enters the scene (bottom).

officer enters the scene. Dust hanging in the air apparently indicates a scuffle. A casual viewer might consider these photos to be compelling evidence in support of a story about excessive force.

There just didn't seem to be very much to go on based on the photos. One can't really see anything clearly. And that's actually quite common, since many photos taken at forensically important scenes are ambiguous. Unraveling them frequently requires a forensic photographic expert. That's where our firm came in.

On closer inspection. Our first step in evaluating the photographs was to determine what we could extract from the images. Because negatives were not available, we digitized the only existing 4 × 6-inch prints and processed the resulting digital image files using histogram adjustment and unsharp masking. These techniques are widely used by scientific and graphic artists to adjust the focus, brightness, and contrast of a digital image to optimally show details of interest. As is so often the case with forensic scene photos taken years before, though, these techniques only slightly increased the visibility of objects and actors in the scene. These photographs just wouldn't yield enough definition to tell us what the actors were doing.

As we sat around brainstorming about the situation, someone complained about the shadows — "If the sun weren't behind our scene, we'd be able to see what was happening." Suddenly it became apparent that those shadows could be our allies, rather than our adversaries. Shadows are cast by the interaction between light and opaque objects — such as buildings, vehicles, and people. Shadows are empirically replicable if you have opaque objects and an illumination source. The objects and the illumination were long gone, but perhaps, we thought, we could recreate all of that digitally.

This wasn't a totally unique avenue of reasoning, because much of our forensic work depends on accurately reconstructing scenes of such incidents as fires, explosions, and crimes. For instance, when a fire takes place, especially a fatal fire, the plaintiff hires an attorney, who gets a couple of investigators. Each of them investigates the scene and takes a few rolls of photographs. The plaintiff's attorneys notify the defendant, whose attorney sends out two more investigators, each of whom takes three more rolls of film. By the time we get involved, we have 200–300 photographs to use for reconstructing a scene that's no longer there. Using photogrammetric and CAD techniques, we can precisely recreate the scene and the spatial relationships of the "actors"— appliances and burn patterns — at a fire scene.

In this case, though, all we had were three photographs and a scene — accurate and complete, except for the actors. We decided to ask some of those actors — the police officers — to return to the scene for a couple of hours, and it paid off.

Returning to the scene of the crime

On a hot, summer Albuquerque afternoon in 1998, all of the officers who had been present at the incident pulled up, one by one, in their patrol cars. We had obtained an "exemplar" red Toyota truck and placed it where Friday's pickup had been, as indicated by the photos. At first, there was a lot of milling around, giving us a chance to shoot photogrammetric control points and get the outlines of the buildings and other landmarks around the dusty parking lot using a reflectorless total station. Soon, the officers began to recall where they had stood in relation to one another at the time the witness had taken the three photographs. They took those positions.

Although four years had passed since the incident, when we assembled the involved officers at the scene, they immediately began to recall things that, in the context of the case, were very interesting. One of the most intriguing facts was that the officers' stories were inconsistent. Their explanations of where they were and what they were doing in those photographs were frequently contradictory. Most concluded that they just didn't recall. Nevertheless, as they tried to act out their years-old behavior, some telling events occurred. Just as we were finishing up our reenactment, one of the officers decided to reholster his Asp, or collapsible tactical baton, by going down on one knee, cocking his arm behind him, and striking the end of the baton on the ground. His pose was oddly reminiscent of something we had seen in the photos, yet not so. It was kind of like a mirror image and it took us a while to figure out what it was. It was the "upraised, striking fist" mirrored in the shadows.

The shadows were the key. The low, oblique afternoon sun that forged the patterns we were seeing in the shadows in the snapshots showed an odd mosaic of dark — in fact nearly black — shadows interspersed with keyholed bright spots where the sun shone through. Where something stopped the sunlight, it was dark. Where nothing stopped the sunlight, it was light. This binary pattern would reveal the locations and identities of the actors in the scene.

Measuring the orientation. To model the shadows, it was vitally important that we determine scene's exact position relative to the sun. Although we had measured the details of the scene — buildings, vehicles, and people — during the reenactment using total station surveying instrument, we now had to go back to the site and use GPS and, believe it or not in this technical day and age, a Brunton compass.

We returned to the scene and measured the precise orientation of the scene's layout. With differential corrections, we achieved submeter-accuracy data. Using the GPS data, we correlated the scene's angle with the sun's angle at what turned out to be a solar time of almost exactly 3:00 PM on January 20, an angle that occurs only twice a year in any geographic location.

Refining the buildings. Using the scene photos as a guide, we measured three-dimensional points that defined the corners of the buildings, as well as fence posts, trees, and other features around the parking lot, using a reflectorless total station that we were beta testing. The total station was ideal for measuring control points such as the upper corners of the structures and places where tree branches converged 20 feet above the ground — places one would have a hard time reaching with a reflector.

Back at the office, we downloaded the data points to a CAD program and produced a three-dimensional basemap. We then used the data points in a convergent-axis photogrammetric mapping program to precisely determine the camera's coordinates when each of the scene photos was snapped. In the CAD program, we created the buildings and other features as three-dimensional, solid entities in their exact locations and orientations.

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Model cars. Next, we obtained three-dimensional models of the vehicles in the photo from a data lab. Although the police vehicles were available as standard models, a Toyota truck similar to Friday's was not. So, we took what the lab had and modified it slightly, adding almost a foot to the cab's length.

And finally, people. Knowing approximately where each participant had been during the event based on our reenactment, we created three-dimensional digital models of each officer in his precise location and stance. To do this, we used posing software that models human and animal figures in every possible position and stature. We did not attempt to replicate clothing, police gear, footwear, or other unique gear.

We combined the resulting digital officers, vehicles, structures, and other details of the scene in a three-dimensional CAD-based map. Next, we assigned surface textures and rendered the entire scene using a software package that works within the CAD program. This allowed us to represent the exact views shown by the witness's photographs.

Using the rendering software, we checked the sun angles against ephemeris data from the National Institute of Standards and Technology. These data provided the sun's precise angle of illumination, which we then used to model the shadows at the precise moment the scene photos were taken.

The art of photogrammetry

Of course, even given the millimeter-level scene measurements we had obtained, the precise locations of the things that weren't there when we did our mapping were a problem. We moved individual officers' positions about in small increments using the CAD program's Solmove command. We conducted the same operation on the vehicles in the scene. Anyone who has tried to replicate the positions of objects in a photograph by digital modeling, or even physical posing, knows how daunting it is to get things just right. We worked and worked, frustrated by not having any empirical method for deciding just what way to go. And then, suddenly, all of the angles and the shadows were perfect.

Friday, was clearly not present when the witness took her photographs.

ASPRS defines photogrammetry as "the science or art of obtaining reliable measurements by means of photographs." The moment when we got things just right, we demonstrated the art aspect of photogrammetry. At that very instant, we knew just where everyone was standing — and where they weren't — when the witness took the photographs.

The renderings, which duplicate Figures 2 and 3, were the basis of our analysis and conclusions. We animated these renderings so we could view each from the same angle that the witness took her photo. Then a viewer could smoothly pan over the top to see what the scene and its shadows looked like from above.

Figure 4 shows the view modeled as seen in the Figure 2 photo. Figure 5 is the same model, with the same illumination, viewed from directly above. When the photo and the modeled image are compared, the dark areas on the photo — where something was apparently blocking the sunlight — would have been caused by a physical object between the sun and the parking lot surface. This means that, when the photo was taken, the object causing the shadow must have been between the legs of the officers or just behind them. The figure (officer) with the arm extended back (most likely closing his collapsible baton) would have been in front of whoever was blocking the sun. In other words, the purported victim would have been behind the officers.

In the modeled version duplicating Figure 3, the situation is similar. Figure 6 is a model at the same angle as the witness's photo shown in Figure 3. Figure 7 shows that scene from directly above. The light that shines under the participants and vehicles reveals that the only possible place any obscuring body could have been is, again, behind the bent-over officers — a very unlikely place for their supposed victim to have been lying down. In both models, there literally isn't enough space for anyone to have been lying in front of the bent-over and crouching officers, by the side of the white, unmarked police car.

In short, our accurate reconstruction and modeling of the locations of structures, vehicles, and participants based on shadows substantiated that the subject, Friday, was clearly not present when the witness took her photographs. We could only conjecture as

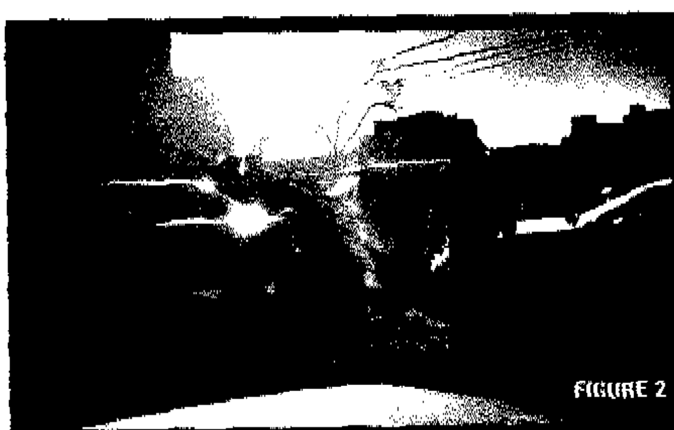

FIGURE 2

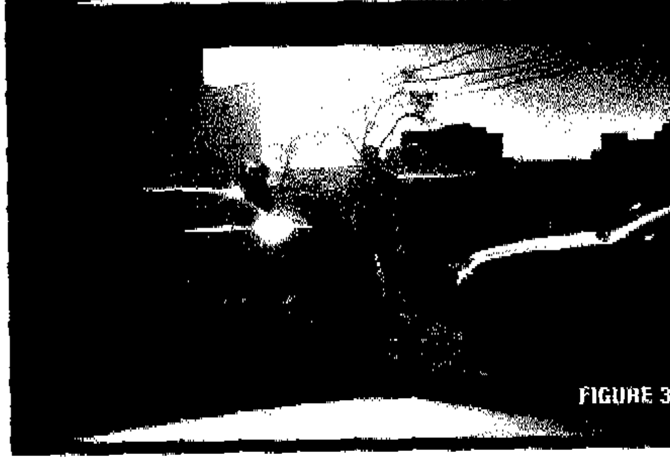

FIGURE 3

to why the witness thought she saw a beating perpetrated by police officers. Perhaps it was because, during the entire course of the supposed incident, she was squinting through the tiny viewfinder of her inexpensive camera and, in the final analysis, couldn't really see what was taking place.

What the officers were really doing when the witness snapped her photos is another question we will never be able to answer. During our reenactment, none of them could really explain or recall — looking at something on the ground, perhaps? All agreed it seemed reasonable that Friday was already restrained and in a police vehicle when the photographs were taken. The photos do not show Friday being abused. In fact, they don't show him at all.

The court threw out Friday's lawsuit.

Manufacturers

To model the shadows in the infamous crime scene photos, **Ebert & Associates** (www.ebert.com) mapped the site using a **Trimble** (www.trimble.com) TTS-500 reflectorless total station. They returned to the scene of the crime and documented GPS positions using a **Sokkia** (www.sokkia.com) Spectrum receiver. They imported the spatial data, the animated people created using Poser Software from **MetaCreations** (www.metacreations.com) and the vehicle models from **Viewpoint Labs** (www.viewpoint.com) into **Autodesk**'s (www.autodesk.com) AutoCAD. They used PhotoModeler and Accurender to create three-dimensional models of the scene.

FIGURES 2–7 The final output of the photo interpretation was an *animated series that rendered* each of the photographs as a georeferenced, three-dimensional, *digital reconstruction, complete with* shadows based on the sun's angle and position *at the time of the incident. Figure 4 is a model of* photographic Figure 2. Figure 5 is the same model as *Figure 4, but as seen from above.* Figure 6 *replicates* the photograph shown in Figure 3 from the same *angle as the witness photo,* while Figure 7 shows that scene from above.