REALITY CAPTURE AND FORENSICS: ADVANCEMENTS IN TECHNOLOGY AND SPATIAL ANALYSIS

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When you are standing in the middle of a site or in front of a piece of evidence, whether it is a construction site, accident site, fire loss, or even a disaster area, it is easy to overlook the significance of the spatial relationships of everything around you. But when there are questions about build plans, risk management, or how an accident or loss occurred, those spatial relationships are often the key. Forensic investigators and other experts rely on measurements of all kinds to analyze the evidence and solve the problems presented to them. Things like the length of a skid mark, the relative location of sprinkler heads, the diameter of a pipe, or the rise and tread of a staircase, offer more to an analysis than just the face value of the measurement. Experts can interpret this data and use it to answer complex questions, but access to evidence might be limited, and not all evidence lasts forever.

The term "Reality Capture" describes the process of acquiring digital data of a site or object and creating accurate digital 3D replicas, or "digital twins" of the world we see. The resulting 3D data can be explored and measured on the computer and is accurate to within millimeters or centimeters depending on the tools and methods applied. Some sensors of these tools also have the ability to capture additional data to help drive an analysis. Reality capture data is so accurate that it often serves as a means of digitally preserving evidence, allowing physical evidence to be released, repaired, or destroyed, and allowing for digital inspection of the evidence even years later. There is a wide range of reality capture tools commercially available today, but certain technologies stand out from the crowd.

Terrestrial 3D laser scanners that utilize light detection and ranging (LiDAR) are often the tool of choice amongst forensic investigators for collecting detailed, highly accurate reality capture data. This technology has been prevalent for over a decade, but over those years, it has become the gold standard for reality capture. Where a traditional survey might capture hundreds of individual data points in a day's work, terrestrial 3D laser scanners capture tens of millions of data points in just a few minutes, and combined data points over a large site can reach into the billions. This LiDAR data is accurate to within millimeters at distances ranging from a few feet to hundreds of meters. It is used to document roadways, vehicles, buildings, bridges, interiors, exteriors, sidewalks, power lines, equipment, people, and more. It is widely accepted as objective scientific data in the courtroom, and it is often used as the benchmark for validating new reality capture technologies. The simplest application of terrestrial 3D laser scanning is using it to take measurements. It is especially useful for measurements that would be difficult, unsafe, or outright impossible with just a measuring tape. In one case study, the concrete slab of a factory floor had heaved significantly, and the first question asked of forensic investigators was, "how much has it heaved?". To answer the question, 3D laser scan data of the exposed slab was captured, measured, and analyzed, drawing topographic cross-sections and applying a colorized height gradient to the 3D data, enabling investigators to view the extent and area of damage overlaid on a section plan of the factory (Figure 1). The second question asked was, "is this an isolated incident or an ongoing problem with the underlying soil?". To determine if the slab was continuing to heave and quantify any changes over time, it was documented two more times over several months. Experts conducted a deviation analysis between the first dataset and the subsequent scans, using color-coded data to visualize any deviation (Figure 2). Ultimately, the LiDAR data allowed experts to conclude that the damage was an isolated incident and not an ongoing problem. Because of the non-invasive nature of terrestrial 3D laser scanning, the entire reality capture process and forensic analysis were conducted without any business interruption.

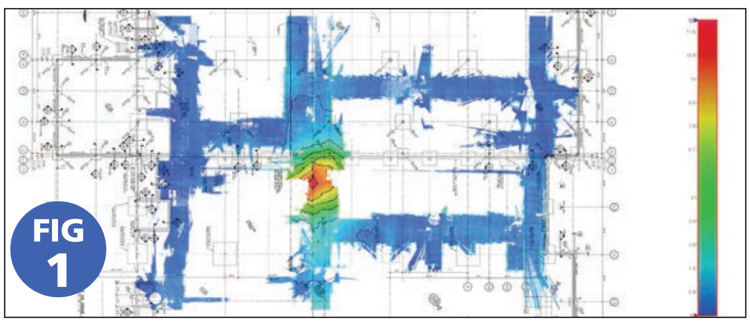
FIG 1

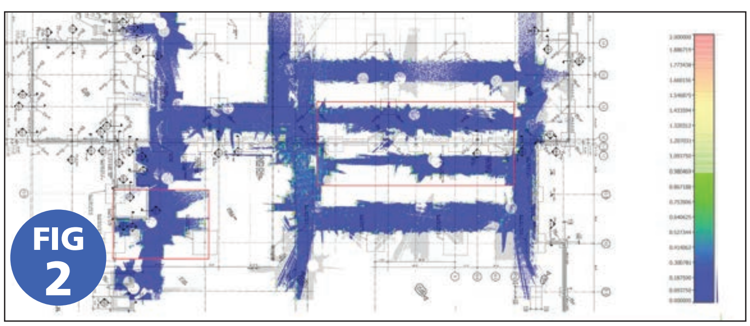
FIG 2

LiDAR offers more than just the measurement from one point to another. Many 3D laser scanners use a camera to collect color information and an infrared laser to measure the distance between the scanner and an object, but that laser beam carries additional information about the object's surface. In a second case study, terrestrial 3D laser scan data was captured of a fire scene. The fully processed data uses the color information from the camera and can be viewed as a 360-degree panoramic image (Figure 3). Like any camera, this relies on visible light to create the image, making it subject to lighting and exposure challenges. The underlying data, however, is captured in the infrared spectrum (Figure 4). This looks like a black and white photograph, but these grayscale colors represent reflectance values of the scanned surfaces. Experts can interpret this information to glean data on the color and/or reflective properties. Where the color photograph relies on visible light and captures all the highlights and shadows, the infrared image ignores the visible light and can even capture data in total darkness. With the infrared's ability to ignore visible light, LiDAR is useful for analyzing surface properties obscured by highlights and shadows, when mapping burn patterns, for example, and it is indispensable when documenting in dark environments such as fire scenes, tunnels, or at night.

FIG 3

FIG 4

FIG 5

Another tool that has become commonplace in the field is UAVs (drones). The use of drones for commercial purposes is regulated by the FAA, but more and more experts are getting their UAV pilot's license to make use of the technology. Aerial imagery on its own can be very useful for getting photos and video of hard or dangerous-to-reach areas, but photogrammetry software makes drones a powerful reality capture tool. Photogrammetry is the science of extracting 3D information from photographs. While it is not specific to drones, an aerial perspective and ability to quickly photograph large or difficult-to-reach areas often make drones preferable to taking photos from the ground. Many professional-grade drones come with the ability to fly predetermined automated flight paths, capturing photos in a specific pattern optimized for photogrammetry that can generate high-quality 3D data. The latest advancement for improving this data is the use of real-time kinematic positioning (RTK), a highly accurate means of spatial positioning. Traditionally, generating 3D data via photogrammetry relied on the images themselves, using common features between photographs to reverse-engineer the camera's position and derive 3D information of the subject matter. This works well, but accuracy of the resulting 3D data over large scenes is generally measured on the scale of several inches, or even feet. By incorporating RTK into the drone's reality capture workflow, photogrammetry software is provided with the camera's position to within a centimeter. This constraint allows for better 3D data, improving accuracy to the scale of centimeters, even over long distances.

One of the newer technologies in forensic reality capture is 3D cameras. These tools combine cameras and photogrammetry with depth sensors and LiDAR to generate 3D data of any space. The accuracy is measured in centimeters, but documentation is fast, taking a fraction of the time terrestrial 3D laser scanning requires. The most prevalent 3D cameras generate 3D models of the space (Figure 5) with platforms to interactively navigate and explore the data online, and AI-driven tools to automatically create floorplan drawings and generate data that feeds directly into common adjusting software.

The future of reality capture is mobile scanning. The top smartphones and tablets now incorporate LiDAR sensors of their own, which program developers are taking advantage of, turning mobile devices into handheld 3D cameras. But as with any exciting new technology, there is a minefield of obstacles to navigate. Since the first LiDAR-equipped smartphone was released in 2020, experts have been testing the capabilities and limitations of scanning with a mobile device. Although there are a select few apps tailored to forensics that can produce quality data, the research suggests that most mobile scanning apps still have some room for improvement before the data can be consistently relied upon for forensic analysis. Ultimately, more research is needed to validate mobile scanning for forensic use, but given current trends, it is only a matter of time before it becomes a reliable reality capture tool in the forensic toolbox.

Whether it is because of time restrictions, physical limitations, or safety precautions, traditional measurement tools can limit an expert's ability to collect all the data they need during an inspection. Reality capture overcomes these challenges allowing for detailed and accurate analysis to be done on the computer. The tried-and-true technologies that have driven forensic reality capture for years continue to improve, and modern technologies are breaking into the forensic space, changing the way spatial relationships are documented and analyzed.

John Swanson is Practice Lead, Imaging Sciences for S-E-A. He specializes in creating demonstrative evidence and other visuals using a variety of 3D, video, photo, and graphics techniques; forensic video and photo analysis; and scientific 3D modeling and animation, aided by over a decade of experience in the field of 3D laser scanning and digital preservation of evidence.