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The Use of a 3-D Laser Scanner to Document Ephemeral Evidence at Crime Scenes and Postmortem Examinations

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Abstract Proper documentation of physical evidence at both crimes scenes and postmortem examination is crucial for downstream analysis, interpretation, and presentation in court. Ephemeral or transient evidence poses particular challenges to investigators, as its very nature renders it difficult or impossible to seize and maintain in its original physical state. The use of a hand-held three-dimensional (3-D) laser scanner is proposed to capture and document such evidence, both in the field and at autopsy. Advantages of the scanner over traditional means of documentation such as photography or casting include the ability to obtain measurements in all dimensions, the ability to reconstruct missing elements, and the ease with which generated images can be interpreted by the jury at trial. Potential scenarios warranting the use of the scanner are identified, and the limitations of its use are discussed.

Keywords: Forensic science; Physical evidence; Documentation; Crime scene; Autopsy; Forensic anthropology; Forensic archeology; Forensic photography; Three-dimensional imaging.

Ephemeral or transient evidence is physical evidence that is temporary in nature and can be easily changed, altered, or lost over time [1]. It cannot be seized and maintained in its original or in situ state. Documenting such evidence presents special challenges to investigators. Traditional methods of documentation include photography, sketches and notes, electrostatic lifting, or casting [2] as well as field forms and video footage [3]. An alternative, supplemental method of documenting transient evidence may be the three-dimensional (3-D) laser scanner. The use of such scanners in forensic contexts has already been discussed in the use of bitemark analysis [4], cranial volume and area measurement [5], morphometric analysis of human facial shape variation [6], general craniometry [7], and documentation of injury at autopsy [8].

Capable of generating high-resolution 3-D digital images, laser scanners are available in both hand-held and stationary units. In the past 10 years, advanced scanners have been developed for surveying, engineering, archeology, and medical purposes. Laser scanners range widely in portability, depending on the intended use of the scanner. Some laser scanners (including those designed for documenting biological material or smaller objects) can be quite large in size. For example, 3dMD's Cranial System requires a dedicated room to accommodate the frame and 5-camera system (http://www.3dmd.com/3dmdcranial.html, accessed July 5, 2010). Some mid-sized scanners such as Eyetronic's FaceSnatcher (approximately US$125,000) are not portable enough to be easily taken into the field.

There are a variety of high-resolution hand-held scanners on the market. Hand-held models usually consist of a single or double headed laser scanner, a transmitter that serves as datum to orient the object and provide scale, and a software package to capture and manipulate the images (Fig. 1). An optional stylus unit allows for specific point information capture and the software includes a ''mark with mouse'' feature that facilitates measurement, image comparisons, and highlights specific features for use in court presentation. The images can then be exported to a variety of 3-D image manipulation software packages such as 3DS Max, Maya, AutoCad (Autodesk), Rhino, or Blender (http://www.blender.org, accessed July 2, 2010). The hand-held units fit in a briefcase for easy transport and require only a power source and a laptop with the appropriate software.

Creaform 3D (Levis, Quebec, Canada) offers a wide selection of hand-held scanners in the HandyScan 3D family, ranging from the entry level UNIScan to the VIUScan, which captures 3-D data in full color. The Leica T-Scan TS50 (Knowhill, Milton Keynes, U.K.) offers a scanner that is able to capture a single object up to 30 m in size. With the increase in laser scanning accuracy, current scanners have the ability to go from part-to-CAD ready, which allows for reverse engineering and advances analyses. Pricing is dependent on the level of accuracy and resolution, whether the device captures data in color, and whether the scans are limited to small parts or larger volume objects.

Unlike traditional digital images, in which resolution is measured in dpi, 3-D laser scan images are saved as microns, which are a measurement of space, rather than pixels. Therefore, direct translation of image resolution to current industry standards is not appropriate. However, image quality and resolution of a laser scan far exceeds that of traditional digital photography. Scanning time per object is minimal and dependent on the number of separate passes or scans of the object with

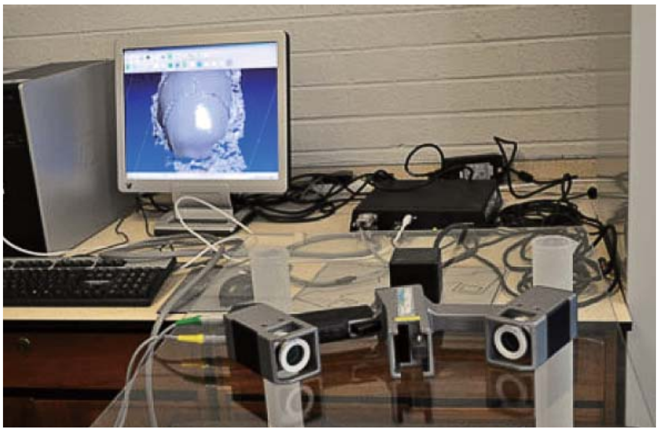

Fig. 1 The Polhemus FastSCAN Scorpion 3-D laser scanner. The double headed hand-held scanner is in the foreground, with the transmitter directly behind. The image on the screen is of a buried skull scanned in situ.

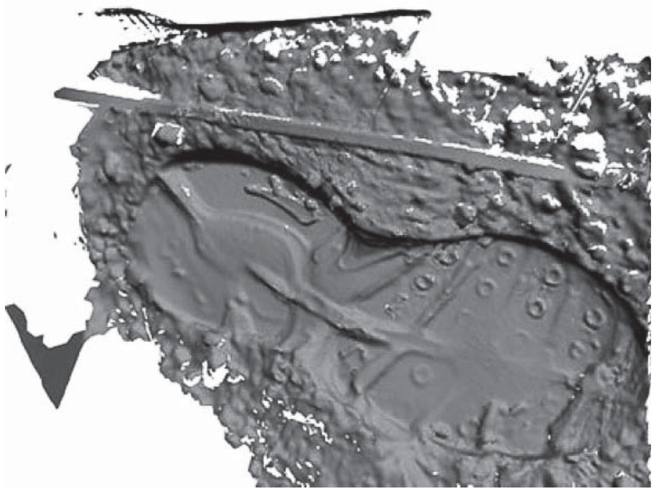

Fig. 2 A 3-D laser scanner image of a footprint impression in fine sand.

the hand-held wand.

The images contained in this article were generated using a Polhemus FastSCAN Scorpion two laser hand-held unit (Colchester, VT). The unit was purchased in 2009 and the total price, including necessary software, was approximately £12,000 (US$18,000). Those with tight budgetary constraints or working in remote areas may even be able to fashion their own laser scanner from materials available at standard hardware stores or home centers (see, e.g., http://homebiss.blogspot.com/2009/02/diy-3d-laser-scanner.html, accessed July 2, 2010). Those utilizing noncommercial or homemade scanners should check that there are no legal impediments to introducing evidence generated by such units in their relevant jurisdictions.

Potential Scenarios in Which to Use 3-D Laser Scanning

Although not comprehensive or exhaustive, the following list provides some indication of the possible field and laboratory scenarios that might benefit from the use of 3-D laser scanning as a supplement to standard documentation.

Clandestine graves. Laser scanning can be used to capture features of the grave walls, including shovel marks for future comparisons against suspect tools, as well as footprint or tool impressions on the grave floor. Because the hand-held laser scanners are capable of recording objects of any size (limited only by file storage capacity), it is possible in theory to scan the entire grave, with remains in situ, as a supplemental source of documentation. Only the transmitter (a small unit) would need to be placed within the grave, to serve as datum and orient all subsequent laser scan passes. With proper use of the equipment, the resolution of the image remains constant for the entire object.

Footprints, tool marks, and other impressed artifacts. Prior to any attempts to cast the feature using conventional methods, a laser scan of the impression can be generated and used in subsequent comparisons against objects suspected of creating the impression (Figs 2 and 3). The 3-D images generated of both the impression and suspect object are then available for downstream analysis and comparison, as well as for presentation in court, providing an easily understood visual demonstration tool for lawyers and juries.

Impressions in materials resistant to standard casting methods. Such impressions include tool, teeth or fingerprint marks in soft, perishable or frozen food items (Fig. 4) as well as footprints or other impression in snow, powder, or other media unsuitable for casting. A recent case investigated by one author (DK) illustrates the potential offered by laser scanning. A homicide victim was buried in a remote location in a grave in which the perpetrator had added a layer of powdered lime, mistakenly believing it had the same destructive properties as caustic lye. The victim was deposited face down in the grave, and the full facial features were captured in the lime in a naturally occurring "death-mask." Photographs of the impression failed to capture the image, and attempts to stabilize the lime powder as a cast were unsuccessful. Subsequent attempts to introduce a casting material into the impression destroyed the lime base and the information was lost. Had a laser scanner been available, an accurate 3-D image of the face could have been rendered without damaging the artifact.

Fire scenes. Burned human remains are exceptionally friable, and their collection, transport, and analysis require special handling (see, e.g., Fairgrieve [9]). Of particular concern is evidence of trauma in burned and degraded remains, which can be damaged or lost during exhumation or recovery. In situ laser scanning can capture images of friable remains that will degrade upon collection and handling, providing 3-D models of remains preferable to 2-D images available from conventional photographs.

Mass graves in human rights investigations. Laser scanners can be used to capture tire, bucket teeth, and other impressions associated with heavy equipment used to form the grave, as well as shovel marks and other impressions visible in the grave walls. 3-D images can also be rendered of features that may be disturbed or dissociated during the recovery process, including blindfolds and ligatures, ephemeral personal effects such as degraded photographs, identification cards, or decomposing clothing, or biological materials such as food stuffs, plant remains, or other perishable items. Skulls with gunshot wounds or other traumatic defects can be scanned in situ, allowing for easy reconstruction of the fragments of the skull in the laboratory.

At postmortem. In addition to standard photographic protocols, capturing 3-D images using a laser scanner should be considered in cases involving bitemarks to skin or other tissues [4], skin impressions such as ligature marks or tool imprints, kerf analysis of sharp force injuries [8], and skeletal cranial remains for use in facial reconstructions or osteological analysis [5,7]. Scanning the texture of an organ at autopsy can document pathological conditions such as cirrhosis of the liver, which causes lesions that are difficult to document well in 2-D photographs. A final novel use of the laser scanner involves cases in which visual identification of the remains by a family member is required. The laser scan can be used in lieu of viewing either a photograph or the actual remains to ease the anxiety of the next-of-kin or in cases in which mild decomposition or other postmortem changes may render the remains disturbing to the family members, as such changes can be modified or removed on the 3-D image prior to viewing by the family.

Fig. 3 A 3-D laser scanner image of the suspect shoe. Manipulation of the images in Figs 2 and 3 with an imaging software permits direct comparison and provides a demonstration tool for court purposes.

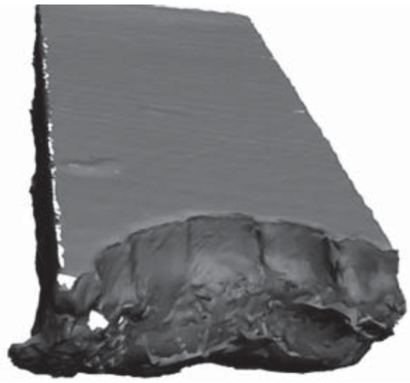

Fig. 4 An example of a laser scan of an impression embedded in media unsuitable for traditional casting. The image is of a bitemark registered in a chocolate coated, soft caramel bar with oatmeal flake base. This image can then be compared to laser scans of suspect dental casts.

Advantages of the Technology

Advantages of laser scanners over other 3-D imaging technologies (such as computed tomography [CT] or magnetic resonance imaging [MRI]) include relative cost of the initial equipment and subsequent maintenance, speed of image generation, portability, equal or greater spatial resolution of models generated, and that the low-energy light used by laser scanners is nonhazardous to the operator and biological specimens under examination [5,10]. One final advantage of laser scanning over CT or MRI is that laser scanning is user friendly and easily mastered with minimal training, typically provided by the scanner's commercial supply house as well as on-line user tutorials.

The benefits of laser scanning over conventional photography include the potential to generate accurate, reproducible measurements from the 3-D image [5]; information discernible in three but not two dimensions; the ability to manipulate 3-D images using alternative software programs (including the potential for animations or other demonstrations for court purposes); and the ability to reconstruct missing elements from partial evidence, such as filling in absent or damaged cranial bones for the purposes of a computer generated facial reconstruction. Ambient lighting also has no impact on the performance of the scanner, unlike traditional photography. The image is generated by a series of laser beams, which operate independent of scene lighting. Unlike photographs used for video superimposition or other identification or comparative techniques, which must be shot in the same orientation as the suspect image, the 3-D images generated by laser scanner can be manipulated into any position. Finally, the images generated by 3-D laser scanner can be saved in a variety of formats, making them easily shared with colleagues and consultants via email, should second opinions or assistance be needed or for demonstration purposes in court.

Limitations of the Technology

While the advantages gained by supplementing photography and other traditional methods of documentation with 3-D images are considerable, the use of the laser scanner may be limited by a number of factors. First, the unit requires a power source. Although generators, car adaptors, and other remote power sources offer potential, some scenes are sufficiently remote, dispersed, or otherwise inaccessible as to render this a valid constraint. Second, the cost of the unit may be outside of the budgets of smaller law enforcement units or medico-legal death investigators. Third, incorrect use of the equipment can produce artifacts on the images that can be misinterpreted or misidentified. Proper training and maintenance of the equipment typically overcomes this problem. Fourth, certain types of evidence may not be captured by the laser scanner. For example, an attempt by the authors to image very faint sharp force kerf defects on human rib bones was unsuccessful because of the size and limited visibility of the objects. Some metallic objects, such as a mirror or highly reflective surface, can cause interference with the scan. Highly reflective surfaces may pose problems but can be powder-coated. Some lower end hand-held scanners do not capture complex geometries such as the human skull or mandible well because of inferior resolution quality. There are some handheld units such as the HandyScan 3D that require small targets be placed on the object being scanned to capture surface detail. Often these targets are small reflective stickers that are affixed to the surface. These stickers can be destructive and, in most forensic contexts, would be prohibited as it modifies the object under examination. Finally, those wishing to use 3-D images as evidence in court should review all statutes pertaining to the introduction of digital images within the relevant jurisdiction, particularly those relating to the subsequent manipulation of such images (i.e., animation) for demonstration purposes. To the authors' knowledge, 3-D laser scan images have not yet been introduced in a court of law.

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