cadmicro

Artec 3D

3D documentation of footwear impressions at crime scenes in minutes, no contact needed

Challenge: To compare the accuracy of a portable 3D scanner versus photogrammetry for documenting forensic footwear impressions in soil and sand, while exploring 3D scanning as a replacement for the traditional method of casting footwear impressions at crime scenes.

Solution: Artec Space Spider, Artec Studio

Result: In less than one minute, footwear impressions can be documented in 3D at crime scenes using the Artec Space Spider, with a level of accuracy superior to photogrammetry. Unlike footwear impression castings, these 3D “digital castings” are unbreakable, easy to transport and store, and can be depended upon for many years to come.

Why Artec 3D? Now, footwear impressions can be documented in submillimeter-precise color 3D, without having to resort to messy, complicated, and lengthy (24-48 hours to dry) casting protocols. The Space Spider makes it easy for non-specialists to capture footwear impressions, and then share the scans with their respective forensics teams while still on scene.

Other than DNA, two common types of evidence that can link a specific person to a crime scene are fingerprints and footwear impressions. With all the popularity of TV crime shows and CSI documentaries, many criminals have become smarter, wearing masks to hide their faces, and using gloves to avoid leaving fingerprints.

Yet it’s extremely rare for any criminal to cover or even attempt to modify their footwear. This is why practically every crime scene is filled with footwear evidence that can directly tie a suspect back to the crime.

If documented and collected properly, such evidence can offer up a wealth of details beyond suspect identification, even making it possible to reconstruct part of the crime itself: the type, brand, size, and specific model of shoe, the number of suspects at the scene, their paths moving to, through, and away from the area, and possibly even the sequence of events that took place.

From collection to comparison

After a footwear impression has been collected, either full or partial, it can be compared to thousands of reference shoes via searchable databases such as SICAR, the National Footwear Reference Collection (NFRC), EverASM, and SoleMate FPX.

By finding a match, investigators will see all the class characteristics of the footwear, which are those produced during manufacturing, such as any logos, designs, the tread pattern, etc.

On the other hand, what's known as "individual" or "randomly acquired" characteristics of the shoe won't be found in any of the above databases, since they're purely the result of ongoing wear patterns together with accidental changes. These features set each shoe apart from all others.

They can include scratches, nicks, cuts, holes, abrasions, tiny pebbles, or other material wedged between treads, etc. What makes these combinations of characteristics so critical for linking a specific shoe to an impression found at a crime scene is the astronomically small chance of another shoe having one or more of the same randomly acquired characteristics in the same locations.

Forensic footwear specialist comparing photo of impression with shoe

According to the FBI, the surface area of a size 8.5 shoe's outsole is approximately 16,000 square millimeters. So, if there's even one random characteristic present that's just 1mm in size, whether that's a cut, a pebble, or a scratch, the chance of this showing up on another shoe in that same location is a mere one in 16,000.

That's not even taking into consideration the shoe size and the sole design, as well as the orientation, shape, or size of the characteristic.

Now, if we bump that up to two or three accidental characteristics in the same respective locations on two separate shoes, the chances plummet dramatically: for two, it's one in 127,992,000, and for three, it's a microscopic one-in-683-billion chance.

Linking an impression to a shoe and to a suspect

To see how these impressions are used in an actual crime investigation, let's say that a footwear examiner, using a searchable database, determines that a murder suspect was wearing a pair of size 15 Nike Air Jordan XXXVIs.

The examiner can narrow down their search to finding the wearer of that shoe, but an identification will only be made once they can link the footwear impression made at the scene to the actual shoe via the corresponding individual characteristics, the so-called "fingerprint" of the shoe.

Unfortunately, as crucial as they can be to an investigation, footwear impressions are some of the most fragile pieces of evidence found at or around a crime scene. So, they need to be documented and collected immediately, especially if they're outside and vulnerable to the elements of nature, not to mention the risk of contamination by first responders and passersby.

Forensic photography & casting: traditional documentation and collection methods

Over the years, the procedure for documenting footwear impressions by taking examination-quality color photographs has evolved to where it is today: the camera must be carefully positioned on a tripod with the film plane parallel to the impression, so that every photograph includes a rigid scale on the same plane as the bottom of the impression.

During the collection stage, 2D footwear impressions (latent or patent), made on hard, flat surfaces, have called for either electrostatic, adhesive, or gelatin lifting.

2D footwear impressions ready for forensic documentation

Whereas 3D impressions, made in softer, uneven substrates such as sand or soil, because of their depth characteristics, have required either silicone- or gypsum-based casting solutions such as dental stone, which has been the material of choice for decades now.

The struggles of casting footwear impression evidence

A serious drawback of the casting method is that it's a contact-intensive, destructive process, which means there's only one chance before the original impression has been damaged and is no longer useful as evidence.

As soon as the casting material has been mixed and ready, it must be uniformly poured into the footwear impression at just the right speed. Otherwise, the downward impact of the material can easily ruin the cast even before it's had a chance to harden. This process is greatly dependent on the skill of the crime scene technician.

Other issues may arise with incorrect mixing ratios or when bubbles exist in the mixing material, which can render the cast useless from an investigative perspective, since this is likely to bring about gaps in the final, hardened cast.

Another challenge with this approach is that the casting material often picks up rocks, stones, dirt, grass, twigs, and other bits of debris, so they become part of the cast. Yet before such materials can be picked out of the casts, the casting material first needs to completely harden, otherwise the casts can be seriously damaged.

3D footwear impression cast (dental stone) at a scene

While still at the scene, the cast will take 45 minutes to an hour to set. Only then can it be transported away and safely stored for the 24-48 hours it takes to fully harden, and then cleaned of debris, as required.

If the need arises to collect 3D footwear impressions in snow, a different route is called for. Since while a gypsum-based cast is drying, it's also releasing heat, enough to melt the snow.

To prevent this, a product such as Snow Print Wax® can be sprayed onto the snow footwear impression, while being careful not to spray too closely or apply too much, as these may distort the original impression pattern. Once the spray has dried, the casting material can be carefully poured into the impression.

Forensic footwear impression in snow

Only when the casts are fully dry should they be handled and used for the investigation. Since they'll need to be stored as evidence, both before the trial and perhaps indefinitely, their hefty size and weight will need to be taken into account, particularly since they're also prone to breakage if dropped or mishandled.

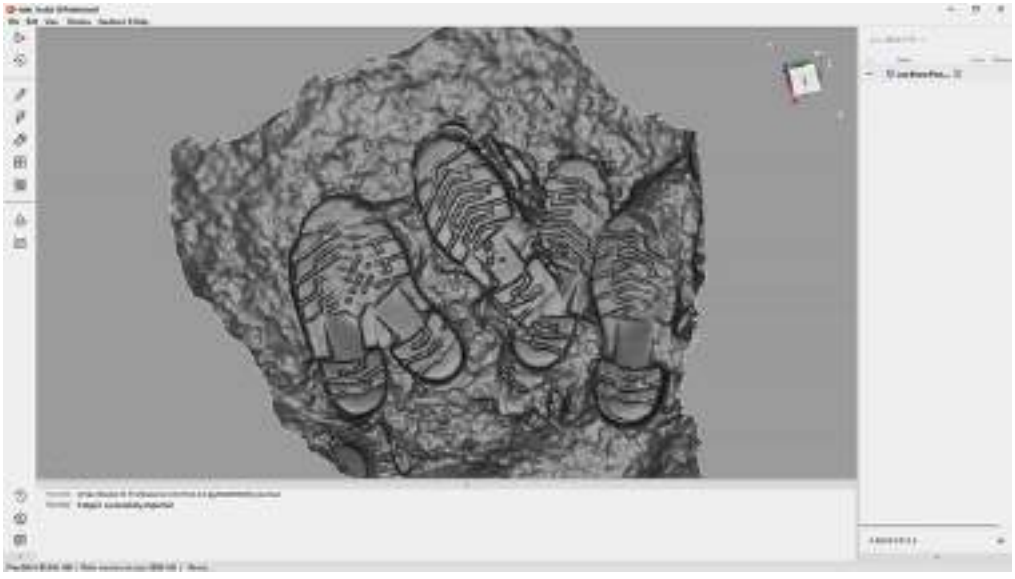
3D scanning for fast & easy, non-destructive evidence collection

More than a century ago, when the father of forensic science, Edmond Locard, announced to the world that "Every Contact Leaves a Trace," perhaps he was also referring to evidence collection methods and how they, without exception, would at least alter if not outright destroy the evidence itself.

Today, more and more law enforcement agencies and investigators are using 3D scanners for documenting and collecting evidence, including footwear impressions. 3D scanners are by nature, non-contact, and non-destructive, making them an ideal choice for the task at hand, as scanning can be done easily and safely, without any risk of damage to the evidence.

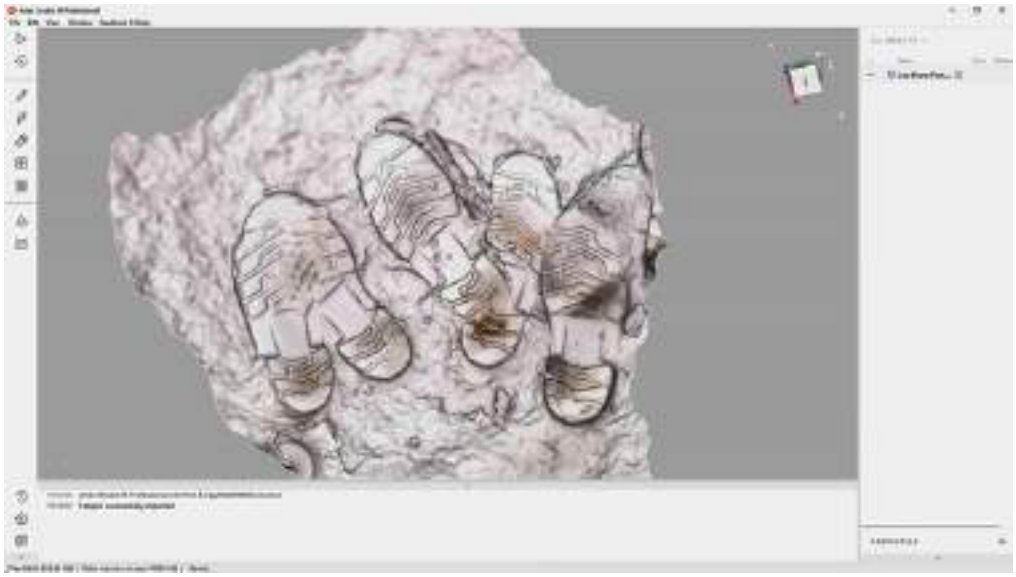
Unlike the hours of waiting needed before footwear impression casts are dry, the resulting 3D models from scanners can be ready just minutes after capturing, even out at the crime scene. They can be shared with other investigators, technicians, and agencies, across the city, the state, or beyond.

Some 3D scanners can also be used to capture footwear impressions in snow, as evidenced by the following two screenshots made after a 1-minute Artec Leo scan of boot prints in snow, in England, courtesy of Artec Gold Certified partner Patrick Thorn.



Artec Studio screenshot showing Leo scans of footwear impressions in snow. Photo: Patrick Thorn

As explained previously, even with special sprays to protect the snow from damage during the casting process, many forensics teams either don't have on-scene access to these tools, or simply don't have the time and resources available to wait for the 24-to-48-hour casting process to conclude.



Artec Studio screenshot showing Leo scans (texture removed) of footwear impressions in snow. Photo: Patrick Thorn

Weighing the evidence: 3D scanning vs. photogrammetry & casting

Recently a forensics research study was carried out in order to understand whether 3D scanning solutions can be a suitable replacement for casting footwear impression evidence, as well as to see how well it compares to modern digital photogrammetry.

The study, Recovery of Footwear Impression Evidence Using Portable 3D Scanning Technologies, was carried out by Ontario Tech University forensic science researcher and student Julia Harvey as part of her FEPAC Accredited Forensic Science undergraduate degree program's Bachelor's Honors Research Thesis.

Harvey accomplished the objectives of her research in collaboration with Eugene Liscio, P.Eng. of ai2-3D Forensics; Theresa Stotesbury PhD, Ontario Tech University; and local police agencies. Central to the study was the Artec Space Spider, a professional handheld 3D scanner that's been a favorite in forensics, paleontology, medicine, and other fields for years, together with Artec Studio software.

Forensic science researcher Julia Harvey using the Artec Space Spider to document a 3D footwear impression. Photo: Eugene Liscio, P.Eng., ai2-3D Forensics

The Space Spider captures up to one million data points per second, with an accuracy of 0.05 mm (the width of a human hair), giving users the power to scan even the most complex of footwear impressions in under one minute, with no targets or markers required.

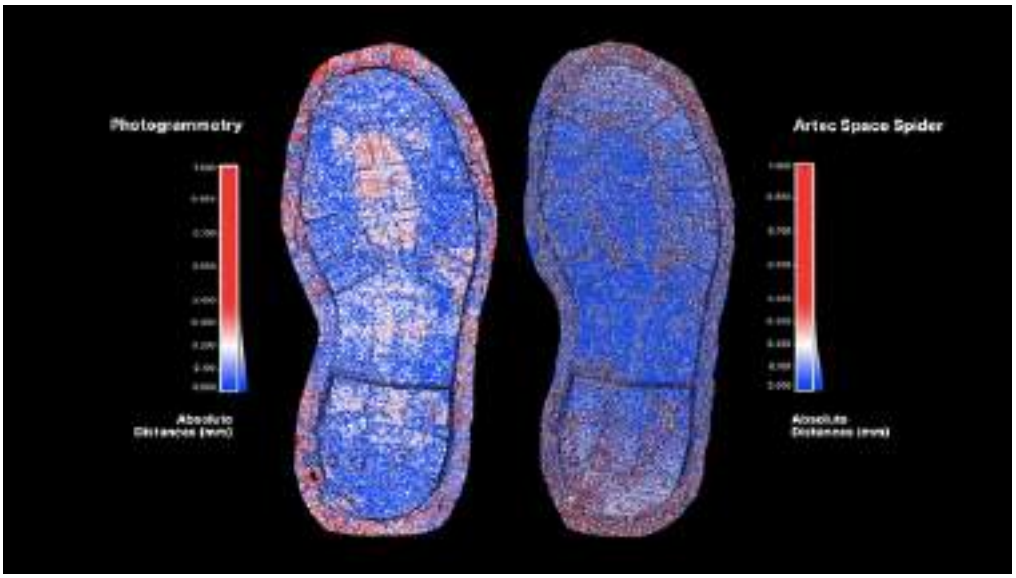
Carrying out the study, step by step

At the heart of the workflow, Harvey created four separate footwear impressions (using a boot and a sneaker) in two different substrates (soil & sand), and performed distance computations in CloudCompare to determine the accuracy of the resulting 3D models from the Space Spider scans versus the 3D models made using photogrammetry. For capturing the impressions via photogrammetry, a Nikon 24.1 MP D7100 DSLR was used.

The results of the study include the following: distance computations between the Artec Space Spider point clouds and high-resolution baseline 3D models made via a tripod-mounted 3D scanner showed that 97% of points had an absolute distance of 0.492 mm or less. The same computations for photogrammetry and the baseline 3D models resulted in 97% of points having an absolute distance of 0.512 mm or less.

Watching the 3D evidence come to life: forensic science researcher Julia Harvey documenting a 3D footwear impression with the Artec Space Spider. Photo: Eugene Liscio, P.Eng., ai2-3D Forensics

“As the results of our study show, with the Artec Space Spider, when it comes to collecting footwear impression evidence at crime scenes, it’s possible for a portable 3D scanner to replace casting. The results are similar to 2D photography, with the added benefit of being able to view all of an impression’s details up close, from every possible angle,” said Harvey.



Heatmap comparison showing the superior accuracy of Space Spider (top) versus photogrammetry (bottom) for documenting 3D footwear impressions. Photo: Eugene Liscio, P.Eng., ai2-3D Forensics

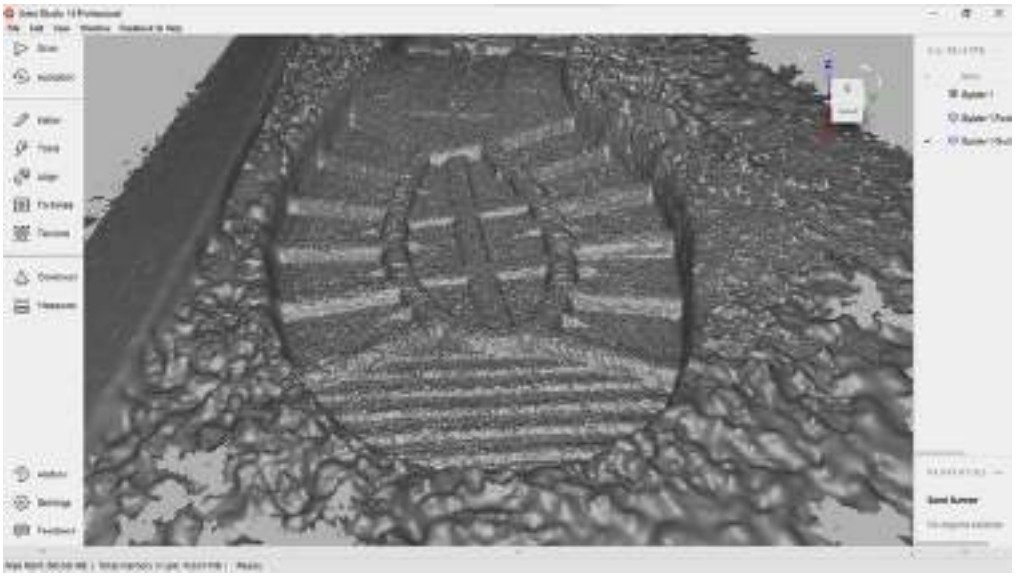
Not that just any 3D scanner will suffice. Typically, professional 3D scanners have much higher accuracy and lower noise levels than cheaper solutions. Harvey's research shows that if too much noise is present in a scan, the impression must be rescanned, and this can multiply the time needed for recovery.

Artec Studio screenshot showing Space Spider scan of a boot impression. Photo: Eugene Liscio, P.Eng., ai2-3D Forensics

Additionally, impressions made in various substrates, such as wet soil, mud, etc., can be challenging for many 3D scanners to capture, due to excessive reflectivity and other issues, so these scenarios should be tested prior to actual crime scene usage, to confirm that the chosen device is able to capture the entire impression, including all the crucial small-class and individual characteristics.

Aside from the accuracy of 3D scanning versus photogrammetry, forensics specialists and agencies benefit from several other aspects, including the following:

- the speed of capture (less than a minute per impression);
- the ability to do analyses while still at the scene (distance calculations between outsole features and individual characteristics);
- easily storing and sharing 3D data between departments and agencies;
- the ability to 3D-print lifelike replicas for court or investigative purposes.



Artec Studio screenshot showing Space Spider scan (texture removed) of a boot impression. Photo: Eugene Liscio, P.Eng., ai2-3D Forensics

Harvey would like to see future directions of research to include the 3D collection of incomplete footwear impressions, along with impressions made in different substrates, or in different weather conditions. 3D comparisons of known footwear to unknown impressions could also be useful for law enforcement agencies.

“Beyond capturing footwear impressions at crime scenes, professional 3D scanners can do so much more, from documenting bloodstain patterns, bullet holes, human bodies and remains, as well as weapons, tools, and other objects, including the entire scene around. I believe we’re just seeing the beginning of what 3D scanning can do in forensics and elsewhere,” said Harvey.

3D-printed scale models of forensic footwear impressions, for demonstration purposes. Photo: Eugene Liscio, P.Eng., ai2-3D Forensics